INTERNATIONAL SCIENTIFIC JOURNAL

INDUSTRY 4.0

ISSN (PRINT) 2534-8582
ISSN (WEB) 2534-997X

YEAR VII ISSUE 6/2022

PUBLISHED BY
SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
“INDUSTRY 4.0”, BULGARIA

INTERNATIONAL SCIENTIFIC JOURNAL

INDUSTRY 4.0

YEAR VII, ISSUE 6 / 2022

ISSN (PRINT) 2534-8582, ISSN (WEB) 2534-997X

PUBLISHER

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY 4.0"

108, Rakovski Str., 1000 Sofia, Bulgaria
tel. (+359 2) 987 72 90,
tel./fax (+359 2) 986 22 40,
office@stumejournals.com
WWW.STUMEJOURNALS.COM

EDITOR IN CHIEF

Prof. D.Sc. Georgi Popov, DHC, Technical University of Sofia, BG
Prof. Dr. Dr. Jivka Ovtcharova, DHC, Karlsruhe University of Technology, DE

EDITORIAL BOARD

Members:
Acad. Igor Bychkov, RU
Cor. member Alexey Beliy, BY
Cor. member Svetozar Margenov, BG
Prof. Alexander Afanasyev, RU
Prof. Alexander Guts, RU
Prof. Andrzej Golabczak, PL
Prof. Andrey Firsov, RU
Prof. Bobek Shuklev, MK
Prof. Boris Gordon, EE
Prof. Branko Sirok, SI
Prof. Claudio Melchiorri, IT
Prof. Cveta Martinovska, MK
Prof. Dale Dzemydiene, LT
Prof. Dimitar Yonchev, BG
Prof. Dimitrios Vlachos, GR
Prof. Dragan Perakovic, HR
Prof. Galina Nikolcheva, BG
Prof. Galina Zhavoronkova, UA
Prof. Gerard Lyons, IE
Dr. Giovanni Pappalettera, IT
Prof. Henrik Carlsen, DK
Prof. Idilia Bachkova, BG
Prof. Idit Avrahami, IL
Prof. Inocentiu Maniu, RO
Prof. Iurii Bazhal, UA
Prof. Jürgen Köbler, DE
Prof. Jiri Maryska, CZ
Prof. Katia Vutova, BG
Prof. Lappalainen Kauko, FI
Dr. Liviu Jalba, RO
Prof. Luigi del Re, AT
Prof. Majid Zamani, DE
Prof. Martin Eigner, DE
Dipl.-Kfm. Michael Grethler, DE
Prof. Michael Valasek, CZ
Prof. Milija Suknovic, RS
Prof. Miodrag Dashic, RS
Prof. Mladen Velev, BG
Prof. Mohammed Taleb Obaidat, JO
Prof. Murat Alanyali, TR
Prof. Nafisa Yusupova, RU
Prof. Nina Bijedic, BA
Prof. Ninoslav Marina, MK
Prof. Olga Zaborovskaia, RU
Prof. Pavel Kovach, RS
Prof. Petar Kolev, BG
Prof. Peter Korondi, HU
Prof. Peter Sincak, SK
Prof. Petra Bittrich, DE
Prof. Predrag Dasic, RS
Prof. Radu Dogaru, RO
Prof. Raicho Ilarionov, BG
Prof. Raul Turmanidze, GE
Prof. René Beigang, DE
Prof. Rozeta Miho, AL
Prof. Sasho Guergov, BG
Prof. Seniye Ümit Oktay Firat, TR
Prof. Sreten Savicevic, ME
Prof. Stefan Stefanov, BG
Prof. Svetan Ratchev, UK
Prof. Sveto Svetkovski, MK
Prof. Tomislav Šarić, HR
Prof. Vasile Cartofeanu, MD
Prof. Vidosav Majstorovic, RS
Prof. Vjaceslavs Bobrovs, LV
Prof. Vladyslav Alieksieiev, UA

C O N T E N T S

TECHNOLOGICAL BASIS OF "INDUSTRY 4.0"

Role of CAD systems in the context of Industry 4.0
Chukalov Konstantin, Sabev Sabi 201

Analysis of operational data on the work of hydro power plant
Svilen Rachev, Milena Racheva 203

Model driven development of manufacturing execution system based on IEC/EN 62264 standard
Ivanova Tsvetelina, Vasilev Plamen, Belev Yordan 208

Using blockchain technology for ID management: a case study for Albania
Elva Lleka, Luis Lamani, Enkeleda Hoxha 213

DOMINANT TECHNOLOGIES IN "INDUSTRY 4.0"

Defect detection by frequency analysis of flexural vibrations of free-free composite beam
Yonka Ivanova 219

Investigation on mechanical properties of Co-Cr-Mo alloy manufactured by selective laser melting
Erdoğan Polat, İbrahim Etem Saklakoğlu 222

Study The Influence of Immersion in The Synthesis of Thin Layers on a Composite Substrates.
M. Aleksandrova, V. Petkov, V.P. Korzhov, I.S.Zheltyakova 226

Development and Production of Molding Equipment and Plastic masses using new compounding formulations, plastic pressing, drying, high-temperature liquid-phase synthesis and properties of a prototype batch of "yellow" paving stones
Gergana Mutafchieva, Lyuben Lakov, Mihaela Aleksandrova, Marieta Gacheva, Gabriel Peev, Dimo Mihaylov 228

Synthesis and characterization of nanostructured hematite for wastewater treatment
Nadezhda Angelova, Savina Koleva, Georgi Yordanov 232

BUSINESS & "INDUSTRY 4.0"

Emissions to air in a seaport caused by cargo dispersion through the handling operations with dry bulks
Deda Đelović 234

SOCIETY & "INDUSTRY 4.0"

Production engineering curriculum in the context of Industry 4.0 – current state of art and necessary changes in AP of Vojvodina and Republic of Srpska
Milenko Sekulic, Mijodrag Milosevic, Stevo Borojevic, Branislav Sredanovic, Andjelko Aleksic, Jovica Ilic 240

Accounting education and sustainability reporting
Eleonora.Stancheva-Todorova 244

On the Possibility of Interpretable Rules Generation for the Classification of Malware Samples
Ján Mojžiš 248

Human factor in industry 4.0 and the role of inter-generational collabotation
Monika Šestáková 251

Classification of Green Energies and Possibilities of their Effective Use
Raul Turmanidze, Giorgi Popkhadze 254

Role of CAD systems in the context of Industry 4.0

Chukalov,Konstantin, Sabev,Sabi
Technical University Sofia, Bulgaria,branch Plovdiv
chukalov@tu-plovdiv.bg

Abstract: *In the article has been analysed the role of CAD systems in the context of Industry 4.0.The fundamental principles of Industry 4.0 have been viewed and which features of CAD systems meet the principles of Industry 4.0 and which do not.The existing classification of designing have been analyzed and a new concept design classification is proposed,according the principles and the concept of Industry 4.0,whitch is more precise and adequate for smart products..*
Keywords*: INDISTRY 4.0 PRINCIPLES,CAD SYSTEMS,MODULARITY.*

1. Introduction

CAD systems obtained the processes of engineering calculations, engineering analyzes, designing.CAD systems are aggregation of technical resources(software and hardware),serving for solving engineering issues.The first CAD system was created in 1957 and continuously CAD systems becomes a fundamental engineering tool.In present CAD systems are part of the modern manufacturing.

Industry 4,0 is merging the physical and virtual world, creating smart products, smart technologies, smart factories. The term was invented in 2011 In Germany.

In many studies of Industry 4.0,CAD systems are part of application of Industry 4.0,therefore is important the principles of Industry 4.0 to be referred to designing and to be analyzed in which conditions usage of CAD systems meet the Industry 4.0 principless.

2.Principles of Industry 4.0 referred to designing

The main designing principles of Industry 4.0 are(fig 1.):

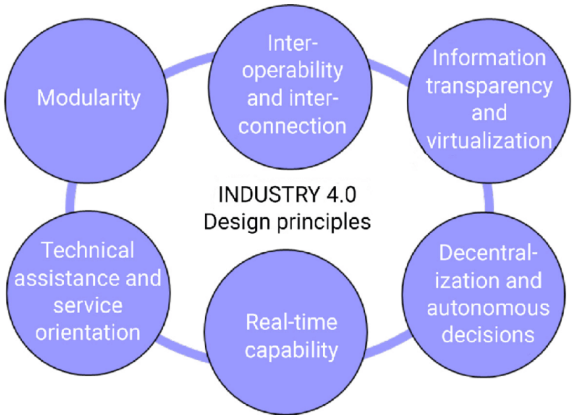


Fig. 1 *Industry 4.0 design principles[1]*

Interoperability and interconnection

Interoperability and interconnection is the capability devise,parts,machines,automation lines, systems, factories ,workers ,objects to exchange data.It is significant principle for Indistry 4.0 because without horizontal and vertical transferring of data it will be impossible to be created a new Industry 4.0 system.Even partial interoperability leads to duplication of data,lost connections and lowed productivity.The goal of Industry 4.0 4.0 is creating a data highway so every smart product to contain data from the designing to recycling(the entire lifecycle of the product.In the context of designing it`s about interoperability between different CAD systems(horizontal communication) and between CAD systems and other software, for example CAD/CAE or CAD/CAM(vertical communication). The subject of compatibility is very large and for full analyze it should be discussed about defined system of software.Generally the results may be full compatibility(entire and full functional transfer of data),full incompatibility(for example even not to open a drawing done by different CAD) and partial compatibility.Despite some solutions like neutral formats,transferring software,usage of familiar software core programs the issue is not fully solved by unifications or standardization.

Virtualization and information transparency means creating a virtual copy of an object.Virtualization may refers to every physical object-part,assembly,automated complexes,factory,city etc.The main goal of virtualization is to collect,summarize and analyze data from the objects.By using virtualization there is no space and time limitations. Digital twins are used for analyzes,tests and eliminate the expensive process of psysical prototyping (equipment ,materials,labor,energy sources etc.).CAD systems are virtual tools,so they fullfill the designing Industry 4.0 principle of virtualization.The degree of virtualization will be relevant to the tools of CAD using during designing.For full virtualization the entire designing process should be in virtual environment

Decentralization and autonomous decision

Decentralization in Industry 4.0 designing means the ability for decision making for every micro level of the system.The decentralization is important regarding the data safety and allows flexibility of the system.CAD systems are single part of the yystem so they are part of the decentralization and also perform autonomous decisions.

Real-time capability

For managing big data ,,selecting and analyzing of real time data is essential.Every delay may lead to wrong decisions,lower productivity and system collapses.This principle is entire related with intercoperability and modularity.Real time capability is also related to other factors like Internet of things,Internet of service etc.CAD systems are real time software so generally fullfils this principle.

Technical assistance and service orientation

Unlike the Second Industrial Revolution, whose goal is to create mass production of individual standardized elements, the goal of Industry 4.0 is to create individual products without losing productivity. Industry 4.0 is fully tailored to consumer requirements.

Modularity

In order to create individual products, production must be modular and adapt to rapidly changing requirements. The more modular the production, the more customer-oriented it is. In practice, "smart products" are different modules. Not necessarily the modules may be of different configurations, may refer to a different color, different material, etc.Modularity and service orientation will be conditionally accepted for one principle,because in the context of designing the bigger volume of modularity will lead to better service orientation. CAD systems can serve both for the design of elements for mass production and individual modular elements.

3 Evaluation of CAD systems according the design principles of Industry 4.0

The tabular assessment is presented in table 1,as grade 1 is for fully match,0 is for partial match and -1 is for fully unmatch.

Table 1: Evaluation of CAD systems according the design principles of Industry 4,0

FACTOR/OBJECT	CAD systems
INTERCOPERABILITY	-1/+1
VIRTUALIZATION	+1
REAL TIME CAPABILITY	+1
DECENTRALIZATION	+1
MODULARITY?SERVICE ORIENTATION	-1/+1

The assessment shows that the usage of CAD does not lead to the implementation of the principles of Industry 4.0.and the entire design process must comply with Industry 4.0 principles.The first step of designing is to classify the type of designing. The design classification will be analyzed whether it is suitable for Industry 4.0 products.

4. Current design classification

There are three types of designing - new, development and adaptive. New design represents the creation of a completely new product, unit, technology, etc., the shape of which is not known in advance. Using adaptive , the design algorithm is known, and the development one is a combination of both.[2]

Smart products created in the context of Industry 4.0 can be classified into all three design groups, which makes their classification imprecise and subjective.. "Smart products" can be classified as the result of new design (new generation design), can be classified as the result of adaptive design (designing configurations, because of the requirement for modularity), as well as the result of development design (designing new functions of already existing products).

This leads to the need for a new classification of design that fully reflects designинг in the context of Industry 4.0.The new design classification should be related to the main principles of Industry 4.0 and should be related to the terms of Industry 4.0.

5. Purposed a new design classification

Taking into account the principles of Industry 4.0, the design should be modular and remodular. Modular design a design principle that subdivides a system into smaller parts called modules, modular design is not a new term, it is widespread in automotive, architecture, information technologists, etc.The proposed classification accurately illustrates the process of designing smart products according to Industry 4.0, as well as contains a major component of Industry 4.0.The new classification of designing divides the designing into two group and it`s simple and precise according the principles.

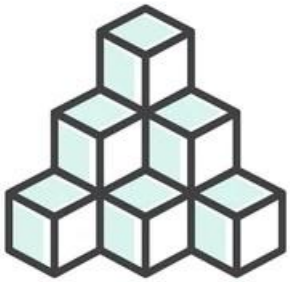


Fig. 2 *Modular designing [3]*

Modular design will be related to creating a new smart product.Modular design in the context of Industry 4.0 will cover the following processes:

- Design of new modules
- The introduction of already existing modules,
- Configuration of existing modules
- Binding (geometric, parametric or logical) of modules
- Creating layers with modules
- Create a network of modules

It`s not necessary every process to be involved,also the sequence for every design may be different according the service orientation. When editing an already existing product, remodular design will proceed. A module is any single component unit that has a customer orientation.One module is not related always with different geometry or type,it may be different colour,material etc.

6. Conclusion

The analysis of the role of CAD systems in the context of Industry 4.0 showed that their use alone does not fulfill all the principles of Industry 4.0 and that without modularity and customer orientation in the design process there is no way to fully integrate Industry 4.0. Another main problem of CAD systems is that there is not always full operational compatibility with other software and hardware, and in this way communication, compliance and horizontal and vertical connectivity are interrupted, which is also an essential element of Industry 4.0. Full operational compatibility is possible with serious efforts towards standardization and the unification of elements.

The article also analyzed the existing classification of design according to the principles of Industry 4.0. Design in the context of Industry 4.0 can be classified into all three types of design, which makes the classification difficult to apply, subjective and imprecise.. A new classification according to the principles is needed, the approaches and terminology of Industry 4.0. A new conceptual classification of design is proposed - modular and remodular design. A module is any single component unit that has a customer orientation.

7.Refferencies

1.https://www.shutterstock.com/search/modularity

2.Chakarski,D.,*Design automation in mechanical engineering*, (1994)

3.https://www.shutterstock.com/image-vector/cubes-graphic-design-template-vector-isolated-1358984906

Analysis of operational data on the work of hydro power plant

Svilen Rachev, Milena Racheva
Technical University – Gabrovo , Republic of Bulgaria
sratchev@mail.com

Abstract: *Paper focuses on the use of renewable energy sources and in particular the use of water energy. A hydro power plant is a complex of facilities and equipment for converting the energy of the water flow into electrical energy. The advantages of hydro power plants are obvious – a supply of energy constantly renewed by nature itself, simplicity of operation, absence of environmental pollution. Taking into account the growing role of small and medium-sized enterprises in the economic development, both of an individual country and on a global scale, as well as the widespread orientation towards the use of renewable energy sources in the production of electricity, the main goal of the current development is the analysis of the operation of the electrical part of a specific hydro power plant with small power. Statistical processing of operational data on the change of certain variables was carried out. In conclusion, it is summarized that the hydro power plant under consideration has good operational indicators.*

Keywords**:** *RENEWABLE ENERGY SOURCES, HYDROELECTRIC POWER GENERATION, DATA ANALYSIS*

1. Introduction

In order to achieve the set goal, namely the analysis of registered data from the operation, the following tasks have been solved:

- consideration of hydro power plant (HPP) as a source of electricity;
- presentation of the features of the activity of a specific hydro power plant;
- calculation of summary indicators from the processing of registered data, based on statistics.

The energy of water has served man for many millennia. Earth's reserves are colossal. No wonder some scientists believe that it would be more correct to call our planet not Earth, but Water - after all, about three-quarters of the planet's surface is covered with water. It is clear that mankind could not pass through the gigantic reserves of water in its demand for energy. The earliest people learned to use the energy of water. But when the golden age of electricity came, the water wheel was revived, but in a different form, in the form of a water turbine. Electric generators producing energy must rotate, and water can do that quite successfully. Moreover, there is already a centuries-old experience of this. It can be considered that modern hydropower was born in 1891.

Nearly 30% of the electricity worldwide is produced by means of hydroelectric power generation and about 88% of the energy coming from renewable sources is hydroelectric [1].

Each HPP is a complex of facilities and equipment for converting the energy of the water flow into electrical energy. The advantages of a HPP are obvious – a constantly renewable energy supply from nature itself, simplicity of operation, low maintenance costs, their life cycle is very long, absence of environmental pollution. In addition, a HPP can reach its maximum output within a few minutes. In comparison, it takes a few hours for a thermal power plant (TPP). The main disadvantage of hydroelectric power plants is that they cannot always maintain a constant load due to the variability of the intensity of the corresponding energy, in this case water energy.

Hydro power plants range from very small micro-hydro power plants to huge dams that provide electricity to millions of people. The distinction between small, mini- and micro-hydro power plants is conditional, although it is accepted in almost all countries of the world that the classification is based on the available installed capacity. The category of small HPPs includes plants with an installed capacity equal to or less than 10 MW, mini HPPs are called plants with a capacity of 500 to 2000 kW, and micro HPPs – up to 500 kW [2].

A hydraulic turbine (water turbine) is a prime mover that converts the mechanical energy of water (its positional, pressure and velocity energy) into the energy of a rotating shaft. A hydraulic turbine uses the force of gravity of water descending from a certain height, called head. The main parts of the turbine are the impeller located on the rotating shaft and the fixed guide jet device located in front of it. Water, under pressure higher than atmospheric, is directed to this apparatus. When exiting narrow openings, it gains great speed. Inside the wheel, this speed is reduced and its direction changed. The resulting inertial forces create a torque in the wheel which is transmitted to the shaft. The electrical generator, usually located on this shaft (in a horizontal or vertical position), converts the energy of the rotating shaft into electrical energy transmitted to the grid. The set of turbine and generator is called a hydro unit. Hydraulic turbines work under head from 2 to 2000 meters. The amount of water passed through the turbine in one second is called flow rate. It reaches up to 800 m^3/s. The power delivered by the turbine to the shaft is proportional to the head, the flow and the coefficient of useful action (efficiency), which determines the degree of use of the energy of the passing water by the turbine and is usually between 0.75 and 0.94.

Existing turbine systems are divided into two classes: active or impulse (free-jet) and reaction (pressure-jet) turbines. The Pelton turbine belongs to the first, and to the second - radial-axial flow (Francis turbine) and axial-flow, divided in turn into propeller (screw) and with reversible blades (Kaplan turbine). The ability of different turbines at the same head and power to operate with good efficiency. at a different number of revolutions per minute of their wheels is evaluated with a special coefficient called rapidity. It has values from 2 to 5 for the Pelton turbine, from 70 to 400 for the Francis turbine, and from 400 to 1000 for the shafts. The lower the head and the greater the power of the turbine, the higher the rapidity of the turbine should be selected.

Inside the impellers of jet turbines, the water pressure is reduced at the expense of high speeds and becomes less than atmospheric. In such cases, a phenomenon called cavitation sometimes occurs. Depending on the needs of the electrical grid for energy, the unit produces and supplies to the network sometimes more, sometimes less energy. The variation of the load on the unit is achieved by adjusting the turbine. At the same time, the automatic regulator changes the position of some parts of the guide apparatus and feeds into the impeller sometimes a larger, sometimes smaller flow.

A hydro generator is an alternating current (rarely direct) generator set in motion by a hydraulic turbine. Usually, the hydro generator is an salient-pole three-phase synchronous generator, the rotor of which is usually attached to the same shaft as the turbine impeller. Hydro generators are built with capacities from 100 to 100,000 kW and more at rotation speeds from 50 to 500 (rarely 1500) min^{-1} and voltage from 400 to 16,000 V.

The frequency of the induced voltage in the synchronous generator depends on the rotation frequency n, [min^{-1}] and the number of stator pole pairs p:

$$f = pn \quad (1)$$

The frequency of the generated voltage is set in advance by the grid (most often 50 Hz). The rotational frequency depends on the type of turbine. In the case of hydropower turbines, n is a small value, but p – a large one. For the turbines of the TPP, n is a large value, and p – a small one.

Due to the relatively low rotation speeds of the hydro generators, at a frequency of the generated current of 50 Hz they have many poles (120 at 50 min^{-1}) and in terms of size and weight they are significantly larger than other electric machines of the same power.

2. Describing of the considered hydro power plant

Hydropower is the most common form of the renewable energy sources (RES) portfolio and produces around 17% of the world's electricity, but its capabilities are limited, in the sense that where possible, such plants have generally already been built. This energy can be highly competitive with other types of energy from RES, given that there are high water falls in Bulgaria and a large annual water flow.

The efficiency of the conversion of the primary resource energy into electricity is the highest in hydropower plants (85-95%), compared to all other energy technologies (Fig. 1) [3].

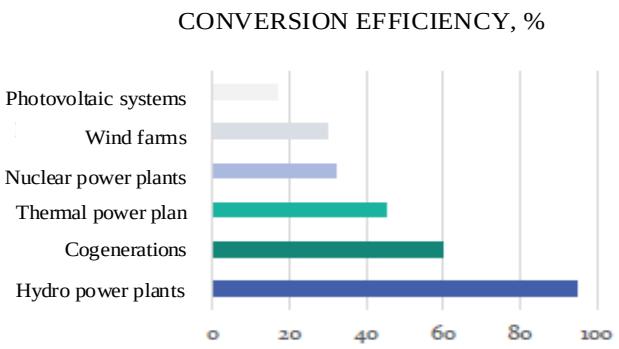


Fig. 1 *The efficiency of the conversion of the primary resource energy into electricity.*

In Bulgaria, over 60% of the renewable energy is produced by hydro power plants, the installed capacities are 3,330 MW, the energy produced by them in 2018 is 5,095,621 MWh, the financial expression of saved CO_2 emissions for 2018 is 10,953,613 BGN million [3].

Out of a total of 92 hydro power plants, more than 2/3 are small, occupying nearly 6% of the installed capacities and 14% of the average annual electricity production in the country. The ownership structure is dominated by privatized small hydropower plants (80.3%), in which a significant part of the installed capacities (92.6%) and the production of the sub-sector (91.9%) are concentrated.

Pursuant to the Law on Energy from Renewable Sources (based on relevant acts of European legislation - directives and regulations, in force from 03.05.2011) a preferential price is set for the purchase of electrical energy produced from renewable sources, including electrical energy, produced by hydroelectric plants with a total installed capacity of up to 10 MW. Hydro power plants with an installed capacity greater than 10 MW are not treated as RES, because other phenomena occur with them - e.g. change of the local climate in the presence of dams, etc. The creation and connection of energy objects for the production of electricity from RES (photovoltaic systems with a total installed capacity of up to 30 kW inclusive, which are planned to be built on roof and facade structures of buildings connected to the electricity distribution network and on real estates attached to them in urbanized territories, HPPs with an installed electrical capacity of up to 1.5 MW inclusive) is under reduced and preferential conditions.

Hydro power plant 'Enina' is located to the east of the village of the same name, at a distance of 8 km north of the town of Kazanlak, at the foot of Balkan in Central Bulgaria. The catchment area is in a national reserve. HPP 'Enina' is a plant with a capacity of up to 1.02 MW, with three hydrogroups in number. The maximum water quantity (water flow) is 1.3 m^3/s, and the head (water fall) – 101.9 m.

The plant has been in continuous operation since its inception until now. It is the oldest operating plant in Bulgaria, built and put into operation on January 1, 1914, it still functions and produces electricity with the old turbines and generators, as it was created. The city of Kazanlak was supplied with electricity on December 31, 1913, at exactly midnight. The city lights up - all businesses and buildings whose owners have trusted the creators. The rapid development of the city begins. The availability of electricity makes it possible to create modern enterprises and factories, and this attracts a lot of foreign capital. By creating the HPP 'Enina', Kazanlak is ahead of cities like Plovdiv, Ruse, Burgas, Sliven and serves as an example to follow. The availability of electricity helps the rapid industrial and cultural rise of the city. In 1937, a new 740 hp hydro generator set was delivered to the plant. On December 25, 1947, the HPP 'Enina' was nationalized and from 1947 to 1993 it was state property. At the beginning of 1994, the plant was restituted to the previous owners, who registered the company 'Pobeda' Ltd. for the purpose. In 1972, a museum collection was created.

An interesting fact is that the construction of the plant was accompanied by many ups and downs. In addition to problems with the builders, the construction activity had to be suspended for a whole year due to the outbreak of the Balkan War, and then the Inter-Allied War. The locals rise up and start sabotaging the work. The first rumor that is spread in the village of Enina is that the electricity on the water will kill the cows that are at the watering hole. Thus, the village sank into darkness at night for many years, while the town of Kazanlak had electric street lighting through a built power transmission line from the HPP 'Enina'.

The amount of electricity produced is strongly dependent on the annual water runoff, i.e. the climatic factor is decisive for the income of the company-owner. For a period of 35 years, for which reliable data is available, the following can be established:

- peak annual production of electrical energy – 4111824 kWh;
- minimum annual electricity production – 1384930 kWh;
- average annual electricity production for the last 35 years is 2581000 kWh.

The technical base available to the company is as follows:

- own buildings (machine room, apparatus room and substation);
- facilities - pressure pipelines, high-speed channels;
- power machines - hydrogroups; control panel, measurement, protection, automation and signaling; closed switchgear; transformers – 3 units for each hydro group, 1 unit each; battery with rectifier for excitation of the generators.

The hydrogroups (three numbers) consist of:

- Turbine horizontal, type Francis (1 piece). The power of the turbine is regulated by a guide apparatus. This hydro unit has downtimes due to design imperfections (rolling bearings on the turbine shaft and an intermediate third bearing in the middle of the shaft). Power 540 kW, rotation frequency Nn = 1500 min^{-1}, made in Germany.
- Pelton type turbines (2 pieces) with a power of 240 kW, rotation frequency Nn = 750 min-1, manufactured in 1912 in

Switzerland. The power of each of the turbines is regulated by two nozzles per impeller.

Although the machines are many years old, their technical condition is good and they are excellently maintained, have no significant defects and have a low accident rate and little downtime. These three hydro groups are located indoors, in an machine room. A general view of the machine room is shown in Fig. 2.

Fig. 2 *A general view of the machine room of the HPP 'Enina'.*

The plant does not have a water catchment basin and the power of operation is determined by the amount of water entering the river. This is achieved automatically by a level regulation device that monitors the water level in an apparatus chamber and changes the load on the turbine so as to maintain a constant level. Reaching extreme 'high' and 'low' levels are signaled and operating personnel start or stop the next turbine.

The electric generators are three-phase synchronous, PFL type, manufactured by 'SIEMENS-SCHUCKERT'.

The following can be briefly mentioned about the company 'SIEMENS':

In 1903, 'SIEMENS & HALSKE' bought the company 'Elektrizitäts-Aktiengesellschaft vorm. Schuckert & Co.', merging it with its own power engineering division, thus forming 'SIEMENS-SCHUCKERT-WERKE' GmbH. The aim of the new company is to cover all areas of electrical engineering. The history of 'SIEMENS' is over 170 years old. Since its founding by Werner von Siemens, the company has grown into a global innovation network with more than 400,000 employees in over 190 countries worldwide.

Данни за генераторите :

- Generator 1: apparent power S_n = 640 kVA; rated voltage U_n = 6.3 kV; power factor $cos\varphi = 0.8$;
- Generator 2 and Generator 3: apparent power S_n = 240 kVA; номинално напрежение U_n = 6.3 kV; power factor $cos\varphi = 0.8$.

The original nameplate of one of the electric generators is presented in Fig. 3.

Fig. 3 *Nameplate of one of the operating generators.*

In terms of technological mode, the primary electrical circuit of the HPP 'Enina' is based on the 'generator-cable-transformer block' principle.

Each hydro group comprises a turbine, a synchronous generator, a line, a step-up transformer. Parallel work to the country's energy system is carried out on 20 kV buses.

The frequency of each turbine is maintained by a turbine generator, which is connected to the shaft of the turbo group by two belt gears: one to drive the centrifugal tachometer and the second to drive the oil pump of the regulator for the turbine guide apparatus or the position of the nozzle needles of the turbine. The turbine is stopped by a hydraulic braking system. In order to safely shut off the water flow when the machine is stopped, a wedge valve is installed in front of each turbine. The temperature of the turbine and generator bearings is continuously monitored by a measuring unit.

All the technological and relay protections necessary according to regulations and rules have been built and are in operation, ensuring continuous and safe operation of the HPP 'Enina'.

All employees have a long experience at the HPP 'Enina', i.e. they are highly qualified specialists with the necessary experience. Every year they take aptitude tests and requalifications according to the requirements of regulations in the energy system. The microclimate is good, provides comfortable conditions for workers, ensuring the health of workers and ensuring good self-esteem and high work capacity.

3. Summary indicators for statistical processing of registered data

Mathematical statistics is applied as a tool facilitating the carry out of scientific research and the accumulation of data in the field of technology. In order to be able to use the apparatus of mathematical statistics, the researcher must first of all be able to find some numerical characteristics and draw statistical distributions, with the help of which the necessary conclusions can be done later.

Cumulative data can generally be thought of as measurements of certain properties of objects selected from some large *population*. Information on certain characteristics of the elements is registered by *sampling*. Elements of the population are the so-called *statistical units* [4].

With the help of *samples* by measurements, some statistical indicators are determined, which are used to draw conclusions about some quantitative characteristics or parameters of the source *population* from which the sample was taken. There are an unlimited number of problems, but still some properties of the distribution of population values are particularly often studied. For example, we are usually interested in the mean value of some population characteristic.

Position characteristics

There are several characteristics of the state of the empirical data population. The most common are the *arithmetic mean value* and the so-called the *median*. In short, the arithmetic mean is the value about which the entire empirical distribution can be "balanced". On the other hand, the median is such a value that one half of the sample values are smaller than it, and the other half of the values are larger (the median divides the area of a possibly drawn histogram into equal halves).

For raw (ungrouped) data $x_1, x_2, ... x_n$ the arithmetic mean is,

$$\bar{x} = n^{-1}.\sum_{i=1}^{n} x_i \qquad i = 1,2,.....n \tag{2}$$

If the sample size is an even number, for example $n = 2r$, then the median can be thought of as half the sum of two means:

$$M_e = \frac{1}{2}.(x_r + x_{r+1}) \tag{3}$$

As a characteristic of the position, a *geometric mean value* can also be used. In the case of sample volume n, the geometric mean is defined as:

$$\bar{\sigma} = (x_1 x_2 ..... x_n)^{\frac{1}{n}} \tag{4}$$

Another characteristic is the *harmonic mean value*:

$$Q_{mean} = \left(n^{-1}.\sum x_i^{-1}\right)^{-1} \tag{5}$$

Dispersion characteristics

One of the most commonly used characteristics of data dispersion is the *mean square deviation*. First, the square of this quantity, called the *variance*, is determined.

For a sample of ungrouped data, the variance is defined as:

$$s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \tag{6}$$

The *mean square deviation* is defined as the positive square root of the variance. For ungrouped data:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \tag{7}$$

In the case of ungrouped data, the formula can be converted to a more convenient form:

$$s = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}}{n-1}} \tag{8}$$

Another dispersion characteristic is the *standard deviation*:

$$\frac{\sum_{i=1}^{n}|x_i - \bar{x}|}{n} \tag{9}$$

4. Results obtained

A set of recorded data on the generated electrical energy from a specific hydroelectric power plant for a period of 2 years was considered.

This real statistical population of statistical units, which in this case are empirical data for active and reactive energy, has been processed, which allows certain regularities to be established based on analysis. The tables made, including calculation results, are implemented according to the rules of statistics [5].

The so-called scattering meters are presented in tabular form [6], respectively arithmetic mean, median, quadratic mean, geometric mean, harmonic mean.

The registered data were recorded by static electronic electricity meters "Schlumberger" at the terminal (lead) ‘Kazanlak’ - 20 kV in the HPP ‘Enina’. The registered data were obtained after establishing professional contacts with representatives of ‘Pobeda’ Ltd. and the operator of the electric distribution network EVN Bulgaria.

Table 1 presents data on sold active and sold/bought reactive electrical energy for the month of April in the second year under review. The bought reactive electricity is necessary for the operation of the excitation of the electric generators, since they work in parallel with the power system, and not independently.

Table 2, Table 3 and Table 4 present calculated summarizing indicators of the produced active electricity during night, day and peak respectively for the two years under consideration.

Figure 4 presents the sold active electricity in kWh for a period of one year for the three reporting zones: I – night, II – day, III – peak.

Table 1: *Sold active and sold/bought reactive energy for the month of April of the second year.*

Zone	Inter-change	New reading	Old reading	Difference	Active electricity sold, kWh	Reactive electricity, kVArh
I - night	*sold*	12700	5400	7300	219000	
	bought	10	10	0		
II - day	*sold*	17300	7800	9500	285000	
	bought	20	20	0		
III - peak	*sold*	12800	6900	5900	177000	
	bought	0	0	0		
Total sold active electricity					**681000**	
I - night	*sold*	1700	1220	480		14400
	bought	650	120	530		15900
II - day	*sold*	2400	2000	400		12000
	bought	2000	600	1400		42000
Total sold reactive electricity						**26400**
Total bought reactive electricity						**57900**

Table 2: *Summarizing indicators of the active electricity produced in zone II - day by the HPP ‘Enina’ for the period of the two years under consideration.*

Indicators					
arithmetic mean	median	quadratic mean	geometric mean for year I	geometric mean for year II	harmonic mean
$\bar{x}$	M_e	s	$\bar{\sigma}_I$	$\bar{\sigma}_{II}$	Q_{mean}
85761,67	82500	73149,27	21513,91	102074,70	10172,7

Table 3: *Summarizing indicators of the active electricity produced in zone I - night by the HPP ‘Enina’ for the period of the two years under consideration.*

Indicators					
arithmetic mean	median	quadratic mean	geometric mean for year I	geometric mean for year II	harmonic mean
$\bar{x}$	M_e	s	$\bar{\sigma}_I$	$\bar{\sigma}_{II}$	Q_{mean}
64966,25	63600	56291,72	13634,91	75118,17	5325,91

Table 4: *Summarizing indicators of the active electricity produced in zone III - peak from the HPP 'Enina' for the period of the two years under consideration.*

Indicators					
arithmetic mean	median	quadratic mean	geometric mean for year I	geometric mean for year II	harmonic mean
$\overline{x}$	M_e	S	$\overline{\sigma}_I$	$\overline{\sigma}_{II}$	Q_{mean}
60623,7	53550	43144,34	24697,77	70598,09	10253,42

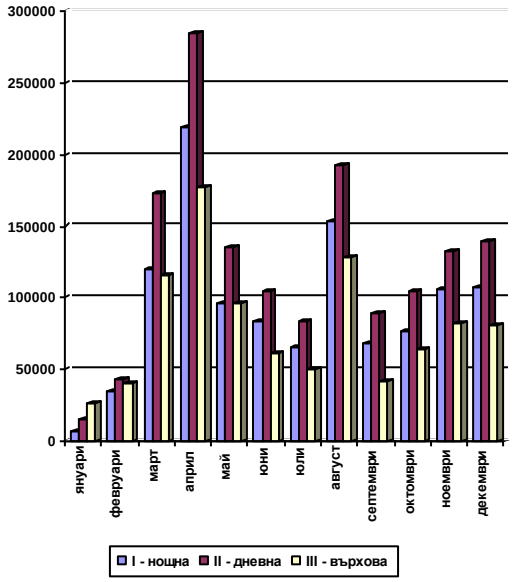


Fig. 4 *Graphic representation of the sold active electricity in kWh for zones I – night, II – day, III – peak for a period of one year.*

As an addition, it should be mentioned that the Bulgarian State Commission for Energy and Water Regulation, as of January 1, 2022, determined an estimated market price respectively for the electricity transmission operator (TSO), the electricity distribution operators and the producers of electricity from hydroelectric power plants with an installed capacity of no more of 10 MW in the amount of BGN 283.48/MWh excluding VAT [7]. Active electricity generated by the HPP 'Enina' is currently being purchased at this price.

From the graphical presentation of the sold active electricity in kWh for zones I - night, II - day, III - peak for one year in Fig. 4 it can be seen that the highest values are in the months of April and August, followed by March and December.

Generators can supply the grid with more power if the driving power on the hydropower side can be increased. The rotational frequency does not change, as it is determined by the mains frequency.

In February of the second monitored year, purchased amounts of electrical energy of 10 kWh at night and 20 kWh during the day were reported. It is likely that there was a failure in one of the turbines or in the transmission mechanisms shortly before 06:00 a.m. when the electricity meter switches between reading night and day energy. In principle, any rotating electrical machine is reversible and can be used as a generator or a motor. If the driving machine (turbine in this case) fails (shuts down), the generator continues to rotate as a synchronous motor, powered by the grid to which it is connected.

5. Conclusions

Statistics is a mathematical discipline that studies the extraction of information through the analysis and interpretation of empirical data using probability theory. Using statistics, the measures of dispersion were determined - arithmetic mean value, median, root mean square deviation, geometric mean value, harmonic mean value. The root mean square deviation is important because it is a more precise measure than the range (i.e., width of variation or the numerical difference between extreme values). The root mean square deviation acts as the most accurate and adequate measure of population dispersion and is therefore the most widely used.

After examining the HPP as a source of electricity and presenting the features of the activity of the HPP 'Enina', the main goal has been achieved, namely the summarizing indicators for the plant's activity have been derived based on registered data for a two-year period.

The advantages of RES are: inexhaustibility and ubiquity; the possibility of their energy being accumulated and then transformed (analogous to photosynthesis in botany); the possibility of building relatively small power plants that do not load the transmission network. Or more generally, the development of renewable and alternative energy sources has a positive effect in the following directions:

• diversification of energy sources;

• more rational utilization of local resources and reduction of imported ones, i.e. greater resource independence of our economy in general and especially in a period of energy crisis, when decentralized resources such as renewable energy provide essential help for the security of supply;

• increasing energy efficiency;

• improvement of the environmental indicators of the Bulgarian energy sector.

As with other sources of energy, the goal of RES is to generate energy at the least cost. However, adequate programs, investments and mechanisms are needed to encourage the further development of this production. The dynamic regulatory environment that has been observed in recent years and the introduction of retroactive measures have a significant negative effect on the financial situation of companies, worsen the competitiveness of hydroelectric power generation and prevent the implementation of new projects in the sector. In order to avoid the adverse consequences of this policy, which will most sensitively affect the price of energy for society, the creation of a predictable regulatory framework ensuring the sustainable development of the sector is an urgent priority.

6. Acknowledgments

The implementation of this paper is thanks to the support from:

- the University Project 2206S 'Applied mathematical investigations in electric power supply and electrical equipment focused on energy and economic efficiency', financed by the Ministry of Education and Science of the Republic of Bulgaria.
- the Project BG05M2OP001-1.002-0023 Competence Center 'Intelligent Mechatronic, Eco- and Energy-Saving Systems and Technologies' financed by the Operational Program 'Science and Education for Intelligent Growth' of the European Regional Development Fund.

7. References

1. Renewables Global Status Report 2006 Update, Wayback Machine, *REN21*, 2006, p. 20.
2. https://bg.wikipedia.org/wiki/
3. https://hidro-energia.org/
4. Moses, Lincoln E. Think and explain with statistics. ADDISON-WESLEY, 1986. pp. 1-3.
5. Moore, David. Teaching statistics as a respectable subject. // statistics for the twenty-first century. Washington, DC, The Mathematical Association of America, 1992. pp. 14-25.
6. Chance, Beth L. Investigating Statistical Concepts, Applications, and Methods. Duxbury Press, 2005.
7. https://www.dker.bg/

Model driven development of manufacturing execution system based on IEC/EN 62264 standard

Ivanova Tsvetelina, Vasilev Plamen, Belev Yordan
Dept. of Industrial Automation, University of Chemical Technology and Metallurgy
Bul. Kl. Ohridski 8, Sofia, Bulgaria

t.ivanova@uctm.edu, plamen.vasilev@uctm.edu, yordanbelev@uctm.edu

Abstract: The need to improve the performance of production systems, related to increasing the level of coordination and integration of all resources and production functions in order to achieve flexibility and higher competitiveness, causes a growing interest in properly describing all processes. The most promising approach is Model Driven Development combined with appropriate standard.
The aim of the paper is to propose a model driven development approach for manufacturing execution system based on IEC/EN 622264 standard

Keywords: MODEL DRIVEN DEVELOPMENT, IEC/EN 62264, MODELING

1. Introduction

The development and implementation of modern methodologies for managing existing manufacturing execution systems is of utmost importance for improving production and cost efficiency, environment protection. In most cases, this also necessitates the modernization of the production systems themselves, including machines or individual units thereof, to implement modern energy-saving control systems [1]. The most promising approach for modernizing existing processes is the model driven one. In this approach the systems are represented as models which correspond to models, various representations are manipulated through model transformations. Model Driven Architecture (MDA) [2] is a Model Driven Development (MDD) initiative of Object Management Group (OMG). It combines different Platform Independent Models' (PIM) transformations to executable applications. MDA is widely known to be the base for reusable domain knowledge and is accepted as a domain engineering technique [3]. PIM represents a conceptual design pattern of functional requirements which is resistible to changes in implementation technologies and software. Its main purpose is to provide a comprehensive solution for application's interoperability and portability as it divides the system design from specific system architecture. MDA uses open standards such as Unified Modeling Language (UML), XML Metadata Interchange (XMI), etc.

IEC\EN 62264 is a standard which provides a bridge between the enterprise resource planning and manufacturing execution systems (MES) [4]. It provides classes which can support the description of available machinery in a production environment, such as conveyor belts, material capability, etc.

The main goal of the research, presented in this paper, is to develop a model driven approach and methods for creating/describing/improving processes of a manufacturing execution system. The project's main task is to define the requirements for a manufacturing execution system based on IEC\EN 622264 standard.

The paper is structured in 4 parts. After the introduction, in Part 2, a short analysis of IEC\EN62264 standard, in Part 3 a short overview of MDA, MDD, UML and UML diagrams, Visual Paradigm, Relational Database is presented and in Part 4 the proposed approach is shown. At the end some conclusions are made.

2. IEC/EN 62264 standard

IEC/EN 62264 is an international standard for integration of enterprise control systems. It is based on ANSI/ISA 95 and provides a framework for data integration on different hierarchical levels in information systems. This standard provides an option for solving the information discrepancy through creating models and objects for conveying and consolidating information between different levels of information [5]. It has five parts:

- Part 1: Models and terminology – describes the domain supervision of manufacturing operations, activities, interface content and connected transactions between the different levels.[6]
- Part 2: Object and attributes for enterprise-control system integration – describes a common interface content which is interchange between the functions for manufacturing control and other enterprise on different levels. [7]
- Part 3: Activity models of manufacturing operations management – defines activity models which enable the control of enterprise system over the system integration. [8]
- Part 4: Objects models attributes for manufacturing operations management integration – describes the exchanged object models and attributes between the activities from Level 3 presented in Part 3 of the standard. [9]
- Part 5: Business to manufacturing transactions – describes transactions as data interchanges between programs performing business and manufacturing activities related to the third (manufacturing operations management) and fourth (planning and logistics) levels. [10]

The standard describes the models for the main available resources at the management operational level, where the data is gathered and consolidated, such as Personnel Model, Equipment Model, Physical Asset Model, Material Model, Process Model and Operations Model. These resources are the heart of operational definition, in a manner of activities for operations like maintenance, inventory, product production, etc. [5]. It describes the interfaces between the enterprise business and manufacturing-control systems (Fig 1).

IEC/EN 62264 standard alleviates the segregation of production processes from business processes and separates the transferred data from concrete manufacturing and business systems implementations [11].

3. Short overview of applied techniques

3.1. MDD and MDA

Model-driven development (MDD) is an approach which refocuses the development from directly writing code to creating models, which represents different perspectives and levels of abstraction [12,13]. In [14] MDD is presented as architectural meta-programming, where values represent models and alterations map models to models. One of the most promising implementations of MDD is Model Driven Architecture (MDA) of Object Managements Group (OMG). It provides a conceptual framework for development and transformations of several models

– Computation Independent Model (CIM), Platform Independent Model (PIM) and Platform Specific Model (PSM) (Fig. 2).

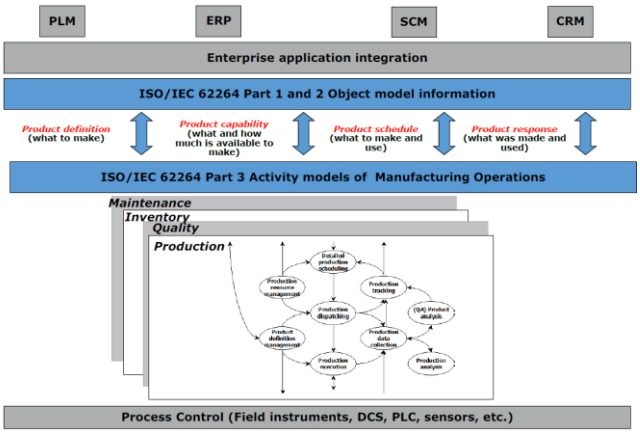


Fig. 1: ISO/IEC 62264 Manufacturing Architecture [11]

Fig. 2: *MDA Conceptual framework*

- **Conceptual Independent Model (CIM)** – is the business (domain) model which presents the main expectations of the system through vocabulary and surmounts the dissimilarity between developers and domain experts. It does not reveal the system implementation's specifications.
- **Platform Independent Model (PIM)** – represents a system view without implementation specifications. Some of its tasks are to establish dependencies, to define processes and workflows and to model logical data.
- **Platform Specific Model (PSM)** – combines the data from a specific platform with PIM specifications, which is necessary for enabling the execution of the system. This model facilitates the generation of the code through the usage of the chosen execution platform and PIM.

3.2. Unified Modeling Language and diagrams

Unified Modeling Language is used to fulfill the necessities of Model Driven Development (MDD) and Model Driven Architecture (MDA). It is a graphical modeling language for design, visualization, documentation and specification of solutions developed during the software development process [15]. "Visual Paradigm" is a software which supports SysML, UML, Business Process Modeling Notation (BPMN); provides DevOps tools, ArchiMate, etc. UML diagrams are used to visualize models and their components [16]. UML 2.5 includes 15 diagrams separated in two main groups (Fig. 3):

- **Structural diagrams –** visualize the static construction of the modeled system and its elements on different abstraction levels. These diagrams include package diagrams, component diagrams, object diagrams, class diagrams, deployment diagrams and composite structure diagrams. Class diagram previews the structure of classes, their attributes, their main CRUD methods and the connection between different classes (Fig. 4).Component diagrams previews the physical aspect of a system through its components and their relationships. Block diagram shows the classes' internal structure and the external communication. Deployment diagrams illustrate the hardware architecture of the software system, visualizing the places of deployment for each software component. Object diagrams visualize the system specifications, including objects with their attributes for a specific time frame. Package diagrams represent the expansion of the system to basic components with their relationships through semantically related elements with their dependencies.

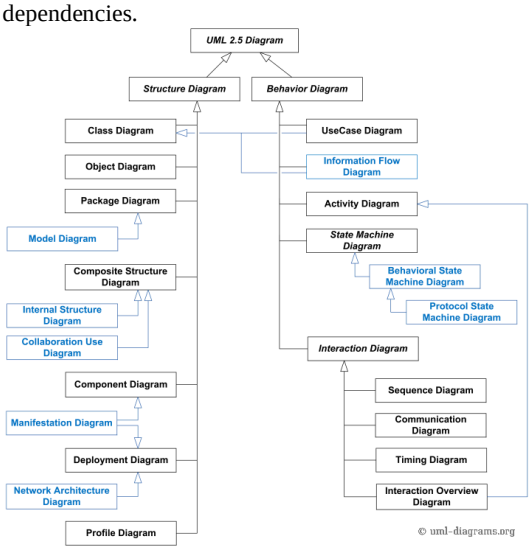


Fig. 3: *Hierarchical organization of UML 2.5 diagrams [17]. The items in blue are not part of the official UML 2.5 taxonomy of diagrams*

- **Behavior diagrams** – visualize the dynamic aspect of the system. They are used to describe the software functionality. They include activity diagrams, state machine diagrams, use case diagrams and the subgroup "Interaction Diagrams", which on its side includes sequence diagrams, communication diagrams, timing diagrams, interaction overview diagrams. Activity diagrams visualize the system operational flows. Use case diagrams represent the dynamic view of the system, through collecting system requirements from both external and internal influences; previews external system view with system operations from the perspective of users (actors) and scenarios (use cases). State machine diagrams illustrate the transition of an object from one state to another. Sequence and collaboration diagrams are used to describe the interactive behavior of the system. Sequence diagrams like interaction-, timing- and communication- concentrate on the message consecution. Timing diagram illustrates the project timeframe. Diagrams of cooperation, like communication and collaboration diagrams, visualize the organizational structure of the involved objects in the interaction.

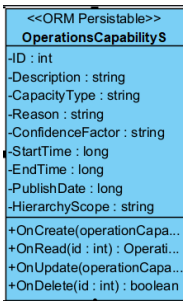


Fig. 4: *Example of a class from a class diagram*

3.3. Relational database

A relational database is an organized collection of logically related data represented through related tables with primary and foreign keys. It is an assembly of different elements such as objects, views, tables, schemas, queries, reports, etc. Databases are typically organized to replicate different aspects from reality in the most suitable way for processing the desired information, this

means that they are logically separated based on application fields. Database management system (DBMS) is a collection of software tools for managing multiple databases including the data itself. It gives access to the data; ability to manipulate the data, the database structure; provides data security; facilitates the data backup; ensures data integrity by creating logs, triggers, locking; and provides interfaces for data manipulation such as SQL interface for relational databases.

MsSQL is a database management system for relational databases created by Microsoft. Visual Paradigm allows database generation through connecting to a desired DBMS.

4. Description of the suggested approach

"Wood Processing SME" is selected as an example of the suggested approach based on the IEC/EN62264 standard. All resource models are described through class diagrams as following "PersonnelModel", "Equipment Model", "Physical Asset Model Class Diagram", "Material Model Class Diagram", "Process Segment Model Class Diagram", "Operations Definition Model Class Diagram", "Operations Performance Model Class Diagram", "Operations Capability Class Diagram". "EqipmentModel" includes the following classes: "EquipemntClass", "EquipemnyCapabilityTestSpecification", "Equipemnt", "EquipemntClassProperty", "EquipemntCpabilityTestResult" and "EquipemntProperty" (Fig. 6). Each class has the corresponding attributes and the main four methods for creating a record, reading/extracting a record, updating and deleting a record. The creating and update methods accept a parameter from the type of the class and accordingly the create method returns the identification number (id) of the newly created record, while the update method returns boolean value (in case of success it is true, else it will be false) (Fig. 4). The reading/extract and delete methods accept an integer value which is the identification number (id, primary key) of the desired record and accordingly return an object and a boolean value (Fig. 4). For each class diagram an Entity Relationship (ER) diagram is generated (Fig. 7). It describes the tables, with all attributes, keys (primary and foreign), indexes and relationships between the different tables. Each class diagram represents a separate database following the requirement to have separation between the databases based on application fields.

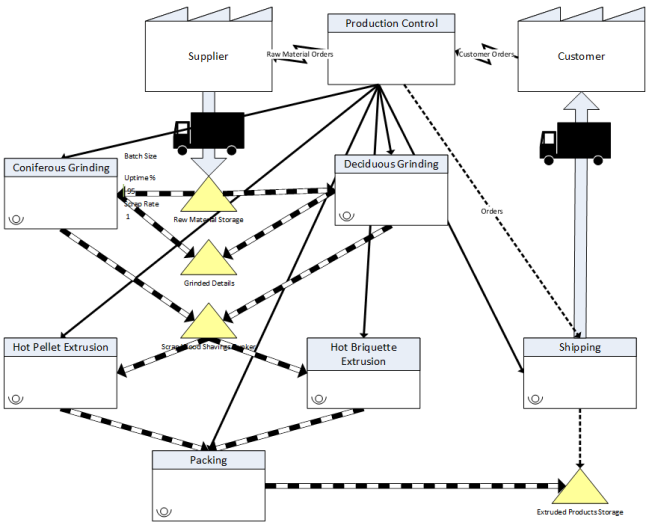


Fig. 5: *Value Stream Map of the process*

As a starting point, the processes may be observed from the business point of view. The process value stream map diagram (Fig. 5) presents only the value-added processes workflows in the production of solid fuels from the residue of furniture production (pellets and briquettes). The definition of the main resources begins with the definition of the portfolio of final products, the establishment of the types of processes and transformations through which the final products pass through. The materials are described by means of the properties that affect the course of the processes and can serve as a classification characteristic. The next stage is the classification of the equipment by means of a detailed specification from the manufacturer, from which characteristics are taken, as well as their main operating conditions and limitations. The same approach is used to define the job descriptions for the personnel who should perform each individual production step.

The products that are being produced as wood bran solid fuel are: Coniferous Pellets, Deciduous Pellets, Coniferous Briquettes, Deciduous Briquettes, Mixed Briquettes and Mixed Briquettes. The main characteristics of the products are Specific Weight and Caloric Content. As both may vary because of many factors as: Plant Species, Humidity, Tree Age, Cutting Season, Density, etc., it can be assumed that the specific weight of coniferous plant is 550 kg/m^3 and for deciduous plants around 900 kg/m^3. As far as caloric value of the products is concerned, the coniferous products may reach caloric values up to 8000 kcal/kg, whereas the deciduous, rarely reach 6000 kcal/kg (due to the higher resin content, at the expense of the lower relative weight). These characteristics will be presented as properties of the Material Definition in the Material Model.

In the Equipment Model the parameters characterizing the grinder are Feeding speed - 20 m/min; Sanding Belt Width - 1200mm; Power Drive - 45-55 kW; Bunker Capacity - 5 m^3;

The Value Stream Map presents two separate grinding processes although the process grinding is one and the same. The reason is that there is a difference in the cycle time, the grinding speed (30 m/s for coniferous and 23 m/s for deciduous) hence the productivity (5 m^2/min for coniferous and 2.5 m^2/min for deciduous), and the scrap waste (bran) relative weight (around 1% - respectively 5.5 kg/m^3 and 9 kg/m^3 grinded material). These parameters will be presented as Material Segment Specifications for the Grinding process.

The Hot Pellet Extrusion process is executed on a vertical pelletizing press with pressing grooved rollers. The extruded product is formed while it passes through an extrusion die with certain dimensions which correlate with the productivity and the extrusion force of the press. The productivity of the press also depends on the bran type, as for the coniferous bran it is around 100 kg/h, and for deciduous bran around 80 kg/h. The Productivity will be presented as Material Segment Specifications for the Hot Pellet / Briquette Extrusion processes. After the extrusion process, the pellets / briquettes are being cooled down for 10-15 seconds and may be subsequently sieved and packed. Sieving and Packing is an automatic process that is executed on a conveying line with Productivity - 6 (15 kg) packs/hour. Here, the Productivity will be given as a Process Segment property.

Conclusions

The design phase of the model driven development aims to acquire knowledge for the processes and to recreate them in an abstract descriptive manner.

The study presented in this paper includes an analysis of the requirements for modeling a manufacturing execution system based on IEC\EN 62264 standard.

The next step is the development of behavior diagrams like activity and use case. An important stage in the research project is the implementation of the approach to an existing "Wood Processing SME" in order to improve the processes and reduce the production cost.

Acknowledgment: This paper has been supported by the Bulgarian National Science Fund under the project KП-06-H27-8/2018, which is gratefully acknowledged by the authors.

References

1. Delijski N., Shehtov H. (2005), Automation and automatization of woodworking and furniture industry
2. OMG-MDA. MDA Guide version 1.0.1. OMG document omg/2003-06-01, 2003.
3. Model Driven Architecture Home Page. OMG, 2011 [Online]. Available: http://www.omg.org/mda/ (Accessed: 31- Oct-2011).
4. Wally, Bernhard & Huemer, Christian & Mazak, Alexandra & Wimmer, Manuel. (2018). IEC 62264-2 for AutomationML.
5. Vasilev P., Metodiev V. (2021), I4.0 Component Models Based on IEC/EN 62264.
6. International Standard (2013), IEC 62264-1:2013, Enterprise-control system integration – Part 1: Models and terminology.
7. International Standard (2013), IEC 62264-2:2013, Enterprise-control system integration – Part 2: Object and attributes for enterprise-control system integration.
8. International Standard (2016), IEC 62264-3:2016, Enterprise-control system integration – Part 3: Activity models of manufacturing operations management.
9. International Standard (2015), IEC 62264-4:2015, Enterprise-control system integration – Part 4: Objects models attributes for manufacturing operations and management integration.
10. International Standard (2016), IEC 62264-5:2016, Enterprise-control system integration – Part 5: Business to manufacturing transactions.
11. Batchkova I.A., Gocheva D.G., Georgiev D. (2017), IEC-62264 Based quality operations management according the principles of industrial internet of things
12. Sellic B., The Pragmatics of Model-Driven Development, IEEE Software, vol.20, no. 5, pp. 19-25, 2003.
13. Banerjee M., Roy S. R., Singh S. N., Model Driven Development: Research Issues and Opportunities, International Journal of Advanced Computer Research, Vol.4 No 2 Issue 15, June, 2014.
14. Batory D., Program Refactoring, Program Synthesis, and Model-Driven Development, In ETPAS Compiler Construction Conference, vol. 4420 of LNCS, pp. 156-171, Springer, 2007.
15. Fowler M., UML Fundamentals, Third Edition / M. Fowler, M.: Symbol-Plus, 2006, 192 pp.
16. Leonenkov A.V., Teach UML, Second edition, St. Petersburg: BHV Petersburg 2004.
17. UML 2.5 Diagrams Overview, https://www.uml-diagrams.org/uml-25-diagrams.html

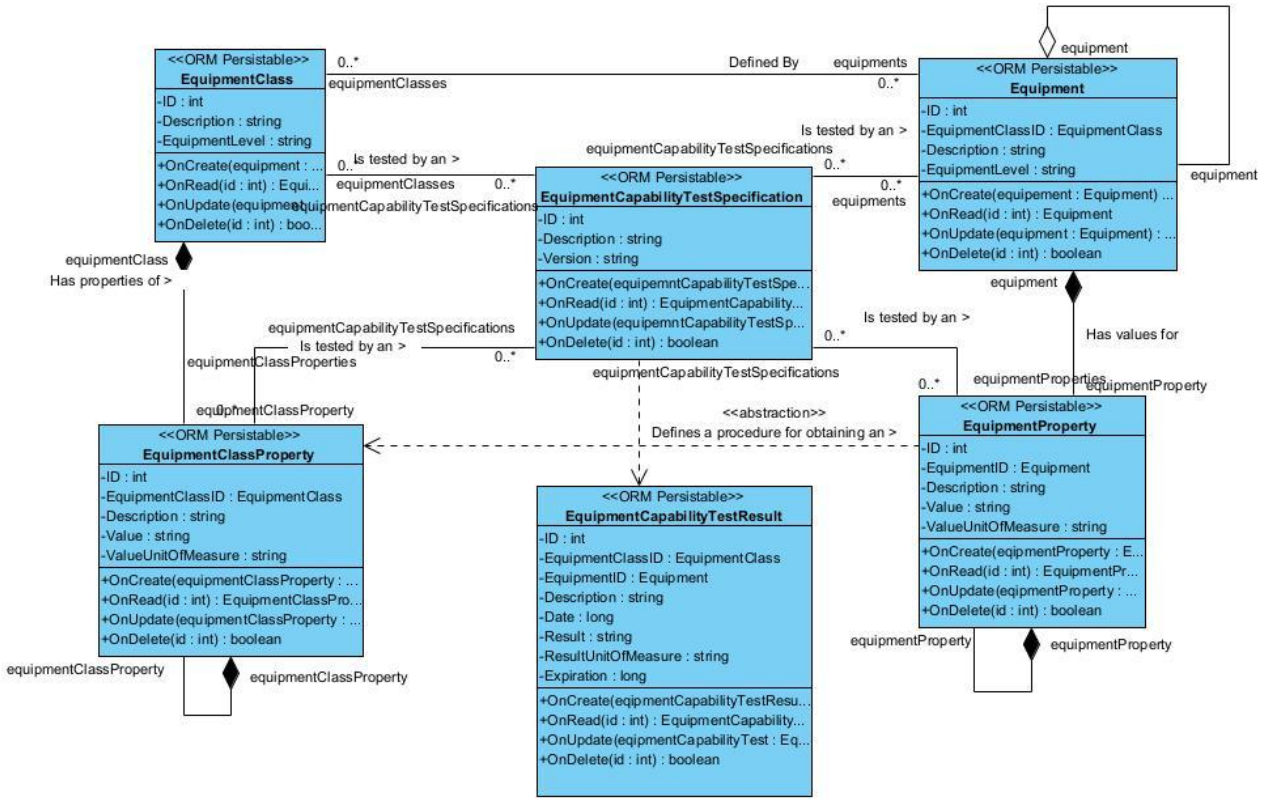


Fig. 5: *Class Diagram "EqipmentModel"*

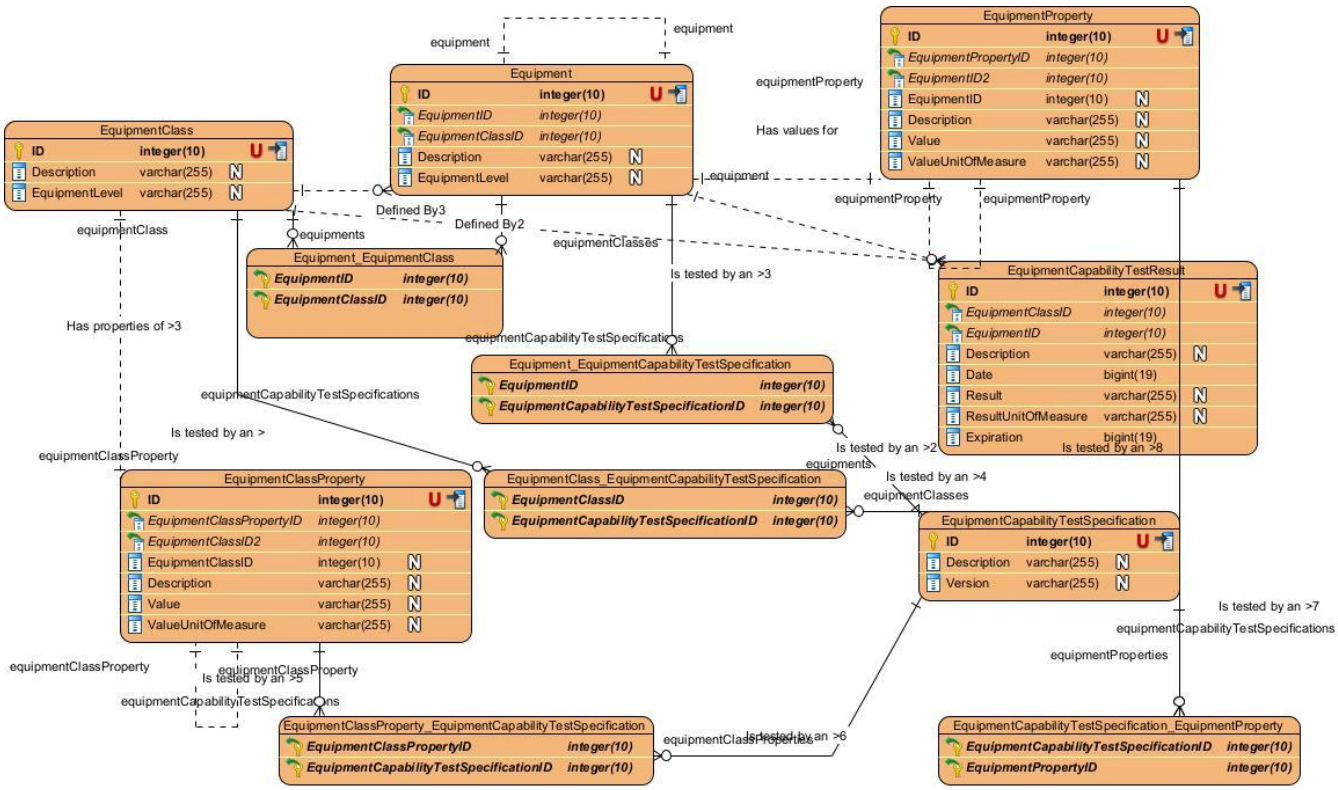


Fig. 6: *Entity Relationship Diagram "EquipemntModel"*

Using blockchain technology for ID management: a case study for Albania

Elva Lleka[2], Luis Lamani[3], Enkeleda Hoxha[1,2]
Polytechnic University of Tirana, Tirane, Albania[1,2]
Albanian University, Tirane, Albania[3]
elva.leka@fgjm.edu.al, luis.lamani@fgjm.edu.al, leda_h@hotmail.it

Abstract - *In this paper we have presented a framework, which proposes to adopt blockchain technology for ID card management in Albania, to increase the security and privacy of personal data. The way how the actual ID cards in Albanian tend to offer security is by using a microprocessor, encrypting the data in the card. However, the centralized data management systems have single points of failure that leave the system vulnerable to attack and operational risks such as: (1) inside hacking, where unauthorized changes of personal information may happen from the inside system; (2) fake digital identities creation or (3) sale of personal identity's data to third interested parties. An answer to address the above-mentioned drawbacks is a decentralized identity management system, which calls for a user-centered strategy and returns complete identification control to the individual. Blockchain technology has the potential to revolutionize modern civilizations and their applications. Administrative processes, security, privacy, integrity and confidentiality are some actions that could have an impact. Furthermore, we present an analysis of previous work on blockchain-based identity management and provide a proposal use case applicable in Albania compared to actual implementation.*

KEYWORDS*: BLOCKCHAIN TECHNOLOGY, SECURITY, PUBLIC ADMINISTRATION, ID MANAGEMENT*

I. INTRODUCTION

A blockchain ID card is a chip which is used to store personal information about the citizen that owns that card, such as: full name, gender, national identification number, fingerprints cryptographic keys, and certificates [1]. In the world we live today with a technologically advanced society, digital identification is gaining great importance. Therefore, it is necessary to create a digital identity system to be positive and sustainable for the long term, and furthermore to be developed as user-centered solutions that enhance user safety, benefit and control [2]. Managing individual identities inside a system, such as a business, network, or even a nation, is referred to as identity management. Our reliance is on identity information management, which aims to manage and secure our personal information while additionally providing related services [3]. Centralized databases are vulnerable regarding identity theft and data breaches. As a result, some nations have looked at and implemented blockchain applications for digital identification. The authentication of many types of identity documents, particularly those used for international transactions, and the prevention of data loss are two issues that blockchain is considered to solve. The possibility of blockchain for self-sovereign identity is also intriguing to stakeholders [4].

A national identity card, which is provided by the government in most countries, is the main system used for both identity verification and at least one functional authentication purpose. Estonia and Finland have also received recognition for their contributions to the advancement of e-government technologies in Europe, among other nations. The Estonian e-Residency system has now developed a new digital nation for world citizens. To safely identify themselves and access e-services, anyone can offer digital signatures using their ID card, Mobile-ID, or Smart-ID. The technology can be used for document signing, banking, payment services, and company registration [5]. Incorporating banking, payment processing, document signing, and company registration are all possible uses for the system.

Creating complete identity management systems that link people's identities throughout their lives—from birth certificates, civil registration records, driver's licenses, and marriage certificates to voter registration and national identity cards—represents a new opportunity for governments [6]. Governments in developing nations are simultaneously expected to carry out many of the same tasks that governments in developed nations can do, including "ensuring universal access to health care and education and administering a wide variety of transfer programs" [7]. The approach, however, has raised security issues because it controls the identification that gives a person their uniqueness. Numerous instances of misuse, duplication, or leakage of highly sensitive personal information, as well as hacking of financial assets, are common. The nation that is harmed suffers economic costs as a result of these security incidents. As a result, managing one's identity becomes a crucial issue for those working in the private sector and higher education also.

Our focus in this paper will be on ID card management. There have been numerous attempts to identify efficient strategies for safeguarding data related to national identification, such as the centralized server that Albania employed while creating its national identity management system. But these methods continue to focus on centralized data management systems with single points of failure, which leaves the system open to attack, because it is possible for an enemy to accomplish its nefarious goals of stealing, abusing, or manipulating the data at the centralized server.

Blockchain technology eliminates the shortcomings associated with centralized data management systems by providing decentralized transactions and safe data management [8]. When Satoshi first proposed the concept in 2008, it was to manage the data for the Bitcoin cryptocurrency. A blockchain is a method for verifying, clearing, settling, tracking, and recording the ownership of assets as they are traded, as not a form of money [9]. This paper uses the identity management system for Albania as a case study to offer a proposal for a protected national identity management system based on blockchain technology. The model addresses user identity disclosure, authentication, and verification. The establishment of a virtual user's true identity on the Blockchain and linking the user's entity information to the metamask address are further ways to thwart Sybil's attacks. Additionally, a handshake protocol paradigm for identity disclosure is proposed, giving users the freedom to decide which identification attribute to disclose to other blockchain users. The creation of a web page prototype for the suggested system is the last phase. The prototype included models that are crucial elements of the recommended national identity management system.

In this article, the sections are divided as follows. In section II we will talk about the general background of blockchain technology and related work that has been implemented in connection with ID management. Then, in section III the current management system in Albania is reflected. The proposed architecture and the implementation are presented in section IV, and the last section V shows the conclusions and future works.

II. BACKGROUND AND RELATED WORK

2.1 Background

Understanding this technology's basic concepts as well as the issues it brings up is essential. Blockchains are collections of information known as blocks, which are linked to one another using various cryptographic techniques. The hash code, confirmation time, and other details identify each block. On the blockchain, there is a digital record of everything we do identifiable, verifiable, storable, and exchangeable signatures are present on every node of the blockchain, enabling a chain of custody to be established from the original owner back to the node [10].

It is important to select a suitable blockchain platform according to the requirements and technical features of a specific implementation. The most popular known blockchain platforms are:

Ethereum, Hyperledger Fabric, Hyperledger Sawtooth, R3 Corda, Stella, etc. [11]. For our implementation, we have chosen the Ethereum platform. Ethereum [12] was developed to expand beyond the scope of a transactional cryptocurrency and utilise blockchain technology to introduce a decentralized framework to the internet. Ethereum is an open platform, and we may use it to easily start a decentralized application and set its own rules for ownership, transactions, and state transactions [13]. Most of the smart contracts are created by using Ethereum. A smart contract is a digital contract, which represents self-executing programs with specific terms and conditions and it would be executed and added to the blockchain network once the conditions are met [14]. A smart contract is designed to remove the requirements for a controller and create a system of mutual trust between participants.

2.2 Related Work

According to our study, several blockchain-based identity systems have been proposed and implemented in different countries.

In their paper [15] authors have introduced a new method of blockchain formation for reliable storage of the personal data of ID-card holders. In order to use the blockchain network for more than only storing ID information and to enable the ability of access control of data as well as boost security, they suggest a novel blockchain structure dubbed “Blockchain Tree”. The authors believe that the solution they propose is more secure and furthermore the methodology for building a storage system, access control, and document verification can be used not only for ID-cards but also for other documents, such as driver’s licenses, education documents, personal medical information, social security cards, etc.

Authors in [16] have proposed a model for a smart card management system using blockchain technology in Bangladesh. They believe that their proposed model will help the government to secure citizens’ private information and bring transparency to their information management.

Estonia is one of the first countries that has implemented the Digital ID, which is powered by the Republic of Estonia. E-Residency is a new brand of digital nation for residents around the world. In contrast to many other nations, every Estonian possesses a state-issued digital identity without any physical touch, regardless of where they live [8]. Every user can securely identify themselves and access services by providing digital signatures with their ID card. The system is accessible to residents for document signing, banking, and payment services [9]. For document signing and document verification, the cards use 2048-bit RSA encryption. The Estonian legal system fully supports the use of this technology for digital signatures on legal documents. The advent of e-Residency is a significant shift, making the recent news that the Estonian government is now collaborating with Bitnation to provide e-Residents with a public notary service based on blockchain technology [17]. The way how identity information is managed and authenticated could be completely altered by using blockchain in e-Residency.

On the other hand, South Korea uses digital driver’s licenses. This is the first digital identification card authorized in South Korea and was approved by the Ministry of Science and ICT in September 2019 [18]. The PASS application uses decentralized identity (DID). A brand-new class of distinct identifiers called a decentralized identifier (DID) is used to verify digital identities that are entirely under the control of the identity's owner. Cryptographic keys can be used by a DID owner to prove ownership of the DID. To confirm the validity of the issuing authority's signature on a credential, one can also use the public key of the Document DID. There are many advantages to using DID technology, but two stand out the most. For starters, because credentials can be verified, it should make it much harder to fake a driver's license. The second important advantage is that an individual can choose how much data to make available to a third party. For example, a driver's license indicates a person's age and using DID, you can prove that you are over 21 without giving your date of birth or even your name [19].

Another proposed digital identity solution is called *ShoCard* [20,21], which integrates blockchain information with facial recognition technologies. ShoCard employs data hashing, out-of-band communication, data matching, and two-factor authentication to safeguard and validate identification. It also uses robust multi-key public/private key encryption. The key topics covered are airline user identification, secure enterprise identity verification, banking institutions, and access to the website and application. It offers a mobile application that lets users save identities and add hashed, signed IDs to the Bitcoin blockchain. Once the user scans their document, the application scans each Machine-Readable Zone (MRZ) and keeps an encoded version on the device. Each field is then broadcast on the blockchain, hashed in a single direction, and signed using the user's private key [20]. The recipient's public key is used to encrypt the local copy of the data before it is transferred via the QR code to any third party for exposure.

uPort [22] is an identity registration method on the Ethereum blockchain. It allows users to authenticate themselves and communicate information with other users clearly and transparently. uPort uses the same cryptography as Ethereum, but for a different reason. The public key is visible to everyone and is used to complete transactions and the private key is more like a secret phrase that only the user knows. The infrastructure required for off-chain data transfer and identity verification is provided by the uPort registry, which is a unique smart contract used by all uPort identities. In essence, it enables identities to assert their identities [22]. In 2017, uPort partnered with the Swiss city of Zug to use its identity management system for municipal services. In November, the Zug government offices organized the first official citizen's identity registration in front of a live audience. Citizens access the service through QR codes and only need to prove their identity once with official documentation [23].

Sovrin [24]: A non-profit corporation called the Sovrin Foundation supervises the Governance Framework that controls the Sovrin Network, a free service that permits self-sovereign identity on the Internet. Users are free to secure, store, and choose the identifying credentials they desire to use, such as a driver's license or employment card, thanks to the decentralized nature of the Sovrin network, which does not rely on separate databases that regulate access to those credentials. In a private setting, the holder of self-sovereign identity can display their credentials that can be independently verified. Information regarding your age, gender, education, and employment are some examples is the data that contains the credentials. The Hyperledger Indy Project and open standards form the sole foundation of the Sovrin protocol. All Sovrin IDs and public keys are aliases by design. Pairwise alias identities, in which each relationship has a unique distributed identifier, provide the solution (DID). Any individual, team, or IoT device that checks the identity owner's credentials can be sure that the proof or information being supplied is accurate and timely when using the Sovrin Network. Additionally, companies can avoid the legal responsibilities that come with maintaining vast amounts of potentially stolen or ill-used client data [25].

III. ACTUALL ID-MANAGEMENT SYSTEM IN ALBANIA

In this section, we will first present the current system which is used for id-management in Albania and the role of AKSHI which is the National Agency of the Information Society. Albania’s present structure The European Agenda 2020 and the Regional Strategy SEE-2020 collaborated to create the Intersectoral Strategy "Digital Agenda of Albania 2015-2020," which aims to improve the digital agenda in a coordinated and efficient manner to improve living conditions for citizens and deliver high-quality services [26].

.

3.1 Albanian ID Card

Identification cards for Albanian Citizens are produced by the concessionary company Aleat Sh.p.k. ID Documents incorporate biometric and electronic elements and use dual-embedded chips which makes it possible to read citizens’ biometric data and identify them. To be able to use the ID card it is needed a card reader called MSO and its drivers, which allow the PC to communicate the IDC microchip and read its data. Security elements are embedded within

Albanian ID Cards: Fingerprint authentication which identifies the owner of ID and electronic certificates allowing the IDC to be used for electronic purposes such as Electronic Signature of eDocuments.

In case an ID document is lost or stolen, the IDC holder can report it or go to the Company service point to revoke its certificates, by making this ID invalid to be used by unauthorized persons or for illegal purposes.

3.2 E-Albania

Albania state has developed a web-based portal, called E-Albania, which is a multifunctional system and serves to provide electronic public services to citizens and businesses 24 hours, 7 days a week. It started functioning as a project invested by European Union in 2009 and now offers more than 600 services, which are offered through various online systems and more than 240 institutions are connected with an e-government portal, increasing interaction between government, society, citizens and business [27].

The Government Interaction Platform, the fundamental architecture that facilitates interaction with the electronic systems of public entities, is linked to the e-Albania government webpage. The mission of e-Albania is to be the main channel for receiving online public administration services for citizens, businesses and public administration employees themselves [28].

The information presented on the platform is updated by the institutions when needed. It is linked to the Government Interaction Platform (Government Gateway), which enables real-time data transmission between 48 systems. The interoperability system is an Enterprise Service Bus solution with a service-oriented design that serves as a versatile central system. The National Register of Civil Status for persons and the National Commercial Register for enterprises serve as electronic databases for the electronic verification of the information users enter throughout the registration procedure. Using NID for citizens and NUIS for businesses, the authentication and identification procedure is based on the "Single-Sign-On" technique to produce a unique identity for each user. More than 50 million transactions are generated per year. Furthermore, 30 different types of documents can be downloaded from the portal equipped with a digital stamp, thus reducing paper use and saving time and money [29].

Other very important benefits that the connection of E-Albania with the Government Interoperability Platform offers are: (1) offering certificates and health cards; (2) facilitation of the flow of electronic information which is necessary to provide public services; (3) exchange of data between systems in state institutions; (4) increasing transparency; (5) offering possibility to analyze large volume of data, frequency of visits, number of transactions performed per visit.

The distinctive, multipurpose government portal e-Albania is developed and managed by the National Agency of the Information Society (AKSHI). AKSHI processes personal data while upholding and preserving fundamental liberties and rights of the individual, including the right to maintain one's privacy [30].

The fundamental architecture that enables interoperability is called Government Gateway. It allows for the integration of all internal government electronic systems. An integration system is required for all internal government electronic information systems to communicate with GG Core. This system will enable communication between internal backend systems and the GG core. Department Integration Server is one of the top options for this integration system (DIS).

The primary government portal, e-Albania can disclose the functionality of these internal systems, facilitating and streamlining citizen service. Messages sent and received between internal systems and between the main portal and internal systems are stored and tracked by an interoperability architecture.

3.3 Cyber Attacks on Albania

The On 15th of July 2022 the e-Albania portal, was unavailable during a cyberattack, which made the system vulnerable, because the attackers accessed sensitive data stored in state computers. The portal was hacked again 2 months later, by penalizing all the services this system offers, by risking all sensitive data, security, confidentiality and integrity. The actors that initiated those attacks have named themselves as *"HomeLand Justice"* [31]. *"HomeLand Justice"* has done a series of attacks for approximately one year before launching cyber-attack, such as: (1) they periodically accessed and exfiltrate e-mail content; (2) included a ransomeware-style file encryptor and disk wiping malware; (3) network reconnaissance, and credential harvesting from Albanian networks (May and June 2022); (4) deployed a version of ZeroCleare destructive malware; (5) On September, actors launched another wave of cyber-attacks against the Government of Albania, using similar TTPs and malware as the cyber-attacks in July.

HomeLand Justice infiltrates the infrastructure of the Albanian Government using DDoS and Ransomware attacks. Due to this, neither residents nor administrative staff could access any administrative services or other types of services. The technique, which involves using malware to freeze data and then leak stolen papers, is frequently used by Iranian hackers.

The Government Gateway Platform is the platform at the center of every state record and the primary system of the Albanian government institutions. It is based on Microsoft products like SQL Server and BizTalk Servers [32]. It makes use of data storage as the database server. A Single Point of Failure (SPOF) is a risk that could arise from a flaw in the circuit of the system's design, implementation, or configuration. SPOF stands for a flaw or failure that has the potential to render an entire system inoperable. And the HomeLand Justice team utilized this exact tactic to access these databases.

IV. BLOCKCHAIN-BASED PROPOSED SOLUTION

In this section, we present the proposed architecture of the application and the implementation part.

4.1 Proposed application architecture

This work proposes a new paradigm for restricted data sharing utilizing Ethereum smart contracts. The decentralized file system, InterPlanetary File System (IPFS), and permission document sharing are the main components of our approach. Each participant has a public and private key, as well as a distinct account address that serves as their network identification. Users, documents, and requesting access data from the institution are the three main components of the above-mentioned approach. As can be seen in Figure 1, a hash code is provided to the user who then sends the data to the blockchain network via the smart contract. When a user enters the information for a document and uploads a picture of it, the information is transmitted to IPFS for storage, and the user receives an IPFS hash that is then sent to the blockchain network via a smart contract. When a user's data is requested by an institution, smart contact is called and the user is informed of the request. The user can then choose to accept or reject the request.

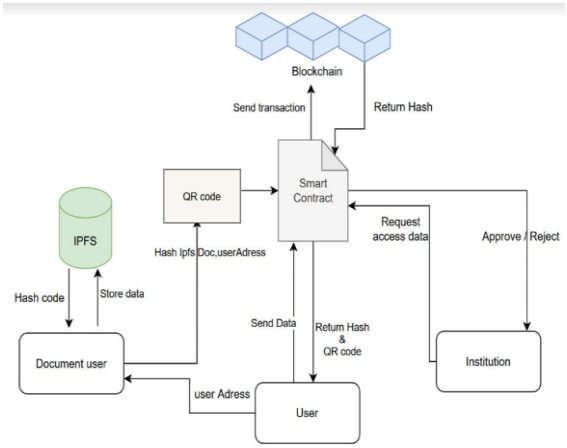


Figure 1. Workflow diagram

Furthermore, Figure 2 presents the level of architecture. The system has some important layers such as: Back-end level, middle

tier (Alchemy, Metamask), IPFS, and Ethereum Platform. To engage in nodes and complete transactions, we have chosen to use the Ethereum blockchain platform, which is a public blockchain. The package list runtime of the localhost URL, or the local server, is entered at the beginning of the prototype flow. After the user selects the package, it will be downloaded and encoded. We prepared to send transactions using our Ethereum address. Then, using Metamask, we sign the transaction on the blockchain. After that, we will combine the data, value, target address, gas price, and gas to create a transaction hash. When we attempt to test the package via a Chrome extension, the same process takes place. We merely need to call the hashing and validations API in the Chrome extension to obtain the outcome.

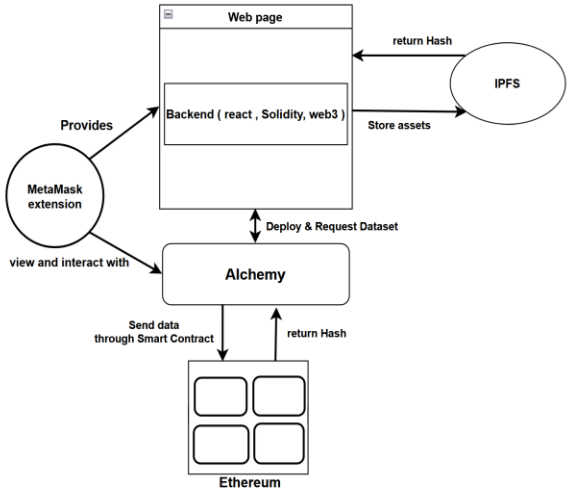


Figure 2. Levels of Architecture

4.2 Implementation

This section presents the main implementation details that have been chosen to connect to the blockchain and then verify on the blockchain network. For the configuration part and to prepare the appropriate development environment we have chosen the following technologies:

- *Ethereum*, as the platform for blockchain network development
- *Solidity*, as the language to deploy smart contracts
- *Metamask*, for the account creation
- *Alchemy*, form building an app to connect the blockchain API to Ethereum
- *"Hardhat"* package/module that will serve to compile the smart contract and run Solidity on a local development network.

After the contract is set up on the blockchain, its specific address is provided to us. We also receive the Binary Application Contract Interface (ABI), which is the standard method for interacting with contracts in the Ethereum ecosystem, both from outside the blockchain and for contract-to-contract communication, along with the contract address.

4.3 Proposed application architecture

This section presents the pseudocodes of the functions we have implemented into our smart contract. The first algorithm looks in the details for a registered person and grants approval after ensuring that no registered person exists in the system with such details. The associated hash is then sent to the user whose registration it is.

Algorithm 1: Add User and submission through Smart Contracts

```
Input: MetaMask Address,
       Full Name,
       Document Number,
       Email Id,
       Mobile Id
ContractState is Verify
UserData is Ready to Submit
If the User is registered = true
       ContractState changes to Wait for Approvals
       UserState is Submit for Approval
       Return: Hash of transaction
End
Else
       Reverse ContractState and Show an error
End
```

This second algorithm, which displays information about a registered user who uploads document data via IPFS, is next presented. *AprovalStatus* changes to 2, if it is approved, or 3 if it is Rejected. After the submission, this data is sent to the blockchain through a smart contract.

Algorithm 2: Add Document User and submission through Smart Contract

```
Input: MetaMask Address,
       Document Number,
       Full Name,
       Date of Birth,
       Document Address,
       Document IPFS Hash
ContractState is Verify
UserData is Ready to Submit
If DocumentHash {UserAdress} = IPFS hash of Document Then
       ContractState changes to Signature provided
       UserState is Submit for Approval
       AprovalStatus changes to 2 {Approved}
       Create a Validation message for successful submitted
End
Else
       ContractState changes to Signature Denied
       Change UserState to Not Provided
       Aproval Status change to 3 {Rejected}
       Create message error
End
Else
       Reverse ContractState and Show an error
End
```

After an institution has made a data request, the final algorithm indicates the user's approval of the data that have been confirmed.

Algorithm 3: Request Access for User Document

```
Input: MetaMask Address of User,
       Contract State Signature Provided
       Name Administration is Provided
If Document No is checked Then
       Change Document No = 1 {requested}
If Document FullName is checked Then
       Change Document FullName = 1 {requested}
If the Document Date of Birth is checked Then
       Change Document DateBirth = 1 {requested}
       If the Document IPFS Hash is = IPFS hash Then
              Change Document IPFS Hash = 1 {requested}
       If message Transaction = successful
              Return: Hash transaction
End
Else
       Reverse ContractState and Show an error
End
```

V. INTEFACES

In this part we present two interfaces for the prototype we have developed, one of which is used for the user menu and the other for the administration menu. First, we need to get the private key that we got when setting up the account through Metamask. With the private key, we can access the account where we are authorized to sign the transaction. Next, we need Alchemy to connect to the Goerli test network. Using React modules: web3 and eth_accounts, specifying parameter values.

Figure 3 presents the Web page of our application, including the main functions of (1) *'User Menu'* which are: 'Create user', 'Add Document' and 'View & Approve Access'; and *Administration Menu* functions, which are: 'Request access', 'View Access Status'.

Meanwhile, Fig. 4 presents the transaction of a 'User creation' and Fig. 5 presents an access request to the user document.

Figure 3. Web Page

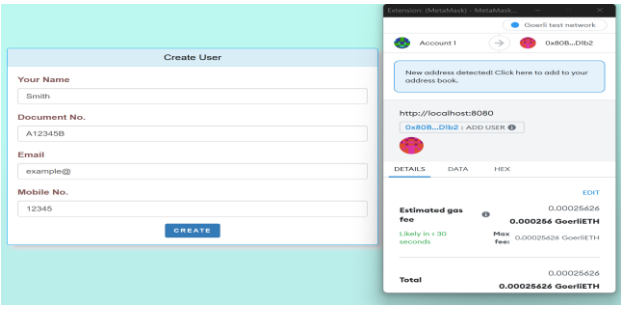


Figure 4. *'Create User' Transaction and Smart Contract Interaction*

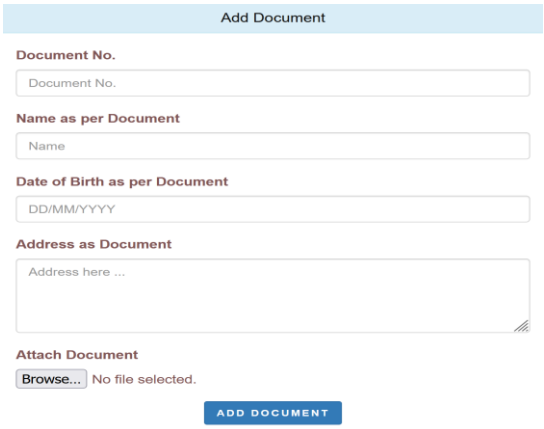


Figure 5. *Request access to the user's document*

Security side: Data structures created by blockchain technology include built-in security features. It is founded on cryptographic, decentralized, and consensus concepts that guarantee the integrity of transactions. The consensus process ensures that each new block added to the Blockchain is the sole version of the truth recognized by all Blockchain nodes. A consensus protocol's goal is to let participants agree on the contents of a blockchain at a certain time (including new blocks). We used the proof-of-stake (PoS) consensus mechanism of the Goerli testnet, a platform for Web3 developers to test blockchain applications before releasing them on the Ethereum mainnet.

VI. CONCLUSION

In many ways, blockchain creates its utility and can be used to close loopholes in a variety of applications. Blockchain is even more advantageous when integrating with the public sector because both sectors have many common values, such as transparency. However, it is important to recognize that blockchain is not suitable for all applications. As a result, defining the requirement and the relationship between the desired use case and the technology is a prerequisite. Furthermore, blockchain may not be the best option when it comes to connecting to legacy systems or moving existing architecture from traditional systems to blockchain-based systems. When it comes to new use cases, blockchain shines. Development, prototyping, and trial-and-error use case experimentation will pave the way for blockchain to mature, just as traditional technology took time to stabilize the current market. This study proposes a blockchain-based national identity management system. The study was guided by the many security ideas of blockchain technology, such as decentralization, proof-of-work, and anonymity, to name a few. These notions gave developers a solution to the problems posed by a centralized data management system. As a result, solutions proposed for secure identity creation and modification, identity authentication model, and identity discovery. Attack prevention also can be achieved by associating a single virtual identity with a physical identity, which prevents users from creating multiple identities on the system.

Despite the efforts made in this paper to meet the stated objectives, more work is required in the areas of identity reputation and third-party access and permission to user information. The handshake working methodology for identity discovery was inadequate and poorly executed. As a result, future research will focus on how to create a comprehensive and flexible handshake protocol that allows users to choose which attributes to reveal to others. The identity management system must have a reputation subsystem that reflects user behaviour in the real world and shows how often users communicate (transact).

Furthermore, as future work, we should also consider some challenges of adapting blockchain in ID management. We can mention here: (1) *data modification*, since it is very difficult to modify of delete it, (2) human errors, because the immutability feature of blockchain requires that information added to the database to be correct; (3) *power consumption*, due to the use of PoW consensus algorithm.

REFERENCES

[1] Jacobs, B., Poll, E. Biometrics and Smart Cards in Identity Management. *In book: Innovating Government*, January 2011, pp. 419-438, DOI: 10.1007/978-90-6704-731-9_23.

[2] World Economic Forum, Committed to Improving the State of the World. I Insight Report – Identity in a Digital World. A New Chapter in the Social Contract. 2018. Available at: https://www3.weforum.org/docs/WEF_INSIGHT_REPORT_Digital%20Identity.pdf.

[3] El Haddouti, S., El Kettani, M. D.E.-C. Analysis of Identity Management Systems Using Blockchain technology. *Proc. of the International Conference on Advanced Technologies and Networking (CommNet)*, April 2019, pp. 1-7, published by IEEE, Online ISBN: 978-1-5386-8317-0, Print ISBN: 978-1-5386-8318-7, DOI: 10.1109/COMMNET.2019.8742375

[4] Lopez, A. M. *Self-Sovereign Identity – The Future of Identity: Self-Sovereignity, Digital Wallets and Blockchain.* September 2020, DOI: 10.18235/002635, Available at: https://publications.iadb.org/en/self-sovereign-identity-future-identity-self-sovereignity-digital-wallets-and-blockchain.

[5] Martinson, P. *Estonia the Digital Republic Secured by Blockchain.* 2019, Available at: https://www.pwc.com/gx/en/services/legal/tech/assets/estonia-the-digital-republic-secured-by-blockchain.pdf, Visited on September 2022.

[6] Gelb, A., Clark, J. *Identification for Development: The Biometrics Revolution*. Center for Global Development, CDG, Washington, 2013, Available at: https://www.cgdev.org/sites/default/files/1426862_file_Biometric_ID_for_Development.pdf.

[7] Tan, E., Mahula, S., Crompyoets, J. Blockchain Governance in the Public Sector: A Conceptual Framework for Public Management. *Government Information Quartly*, Vol. 39, Issue 1, January 2022, pp. 101625 ISSN: 0740-640X, DOI: 10.1016/j.giq.2021.101625, Published by Elsevier.

[8] *The Digital Society, Estonian e-Residency*. Available at: https://e-estonia.com/eresidents/about/, Latest access: October 2022

[9] Sullivan, C., Burger, E. E-residency and Blockchain. *Computer Law & Security Review: The International Journal of Technology and Practice*, 2017. Published by Elsevier Ltd, ScienceDirect, Volume 33, Issue 4, pp.470-481, 2017, DOI: 10.1016/j.clsr.2017.03.016.

[10] Miah, M. S. U., Hossain, M. S., Rupai, A. A. A. *Introduction to Blockchain – Blockchian for Data Analytics.* January 2019, Pubulished by Cambridge Scholars Publishing, UK, ISBN (10): 1-5275-4429-X, ISBN (13): 978-1-5275-4429-1

[11] Mohammed, A. H., Abdulateef, A. A., Abdulateef, I. A. Hyperldeger, Ethereum and Blockchain Technology: A Short Overview. *In 2021 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, June 2021, DOI: 10.1109/HORA52670.2021.9461294.

[12] Sajana, P., Sindhu, M., Sethumudhavan, M. On Blockchain Applications: Hyperledger Fabric and Ethereum. *International Journal of Pure and Applied Mathematics*, Vol. 118, No. 18, 2018, pp. 2965-2970, ISSN online: 1314-3395, ISSN print: 1311-8080

[13] Gopal, N., Biju, J. M., Prakash, V. V. Different Blockchain Platforms and Algorithms. In *International Research Journal of Engineering and Technology (IRJET)*, Vol. 6, No. 3, pp. 4853-4858, March 2019, e-ISSN: 2395-0056, p-ISSN: 2395-0072.

[14] Zhou, H., Fard, A. M., Makanju, A. The State of Ethereum Smart Contracts Security: Vulnerabilities, Countermeasures, and Tool Support. *Journal of Cybersecurity and Privacy*, 2022, 2, pp. 358-378, DOI: 10.3390/jcp2020019.

[15] Kushch, S., Baryshev, Y., Ranise, S. Blockchain Tree as a Solution for Distributed Storage of Personal ID Data and Document Access Control. *Sensor 2022*, Vol. 13, No.2, pp. 3621, Published by MDPI, DOI: 10.3390/s20133621.

[16] Shome, A., Biswas, M., Datta, P., Bhowmik, A. A secured Smart National Identity Card Management Design Using Blockchain. In *2nd International Conference on Advanced Information and Communication Technology*, UIU, Dhaka, Bangladesh, November 2020, DOI: 20.1109/ICAICT51780.2020.9333487.

[17] Tammpuu, P., Masso, A. Transnational Digital Identity as an Instrument for Global Digitalization Residency. *Information System Frontiers*, 2019, Vol. 21, No. 2, DOI: 10.1007/s10796-019-09908-y.

[18] Mapperson, J. One Million South Koreans Now Have Blockchain Drivers Licences. August 2020. Available at: https://cointelegraph.com/news/one-million-south-koreans-now-have-blockchain-drivers-licenses.

[19] Wang, H. Yang, D. Research and Development of Blockchain Recordkeeping at the National Archives at Korea. *Computers*, 2021, 10, 19, DOI: 10.3390/computers10080090.

[20] ShoCard Inc. *ShoCard: Travel Identity for the Future – White Paper*. SITA. Available at: https://canada-ca.github.io/PCTF-CCP/docs/RelatedPolicies/SITA_Identity_2016.pdf, Accessed on: October 2022.

[21] ShoCard Inc. Available: https://shocard.com/ , Accessed on: October 2022.

[22] Braendgaard, P. What is a uPort identity?. February 2017, Available at: https://medium.com/uport/what-is-a-uport-identity-b790b065809c, Latest accessed October 2022.

[23] Young, A., and Verhulst, S. *Self Sovereign Identity for Government Services in Zug, Switzerland*. October 2018, Available at: https://blockchan.ge/blockchange-government-services.pdf.

[24] Sovrin Foundation. Sovrin: A Protocol and Token for Self-Sovereign Identity and Decentralized Trust. A White Paper from the Sovrin Foundation Version 1.0. January 2018. Available at: https://sovrin.org/wp-content/uploads/Sovrin-Protocol-and-Token-White-Paper.pdf, latest access: October 2022.

[25] Windley, Ph. J. Sovrin: An Identity Metasystem for Self-Sovereign Identity. Frontiers in Blockchian, Vol. 4, July 2021, DOI: 10.3389/fbloc.2021.626726.

[26] AKSHI. Axhenda Digjitale e Shqiperise 2022-2026. Available at: https://akshi.gov.al/wp-content/uploads/2022/06/vendim-2022-06-01-370-Agjenda-Digjitale-e-Shqiperise-22-26-dhe-plani-i-veprimit.pdf, Latest access: October 2022.

[27] E-Albania Portal. Available at: https://e-albania.al/, Latest access: October 2022.

[28] Elezaj, O., Tole, Dh., Baci, N. Big Data in e-Government Environments: Albania as a Case Study. Academic Journal of Interdisciplinary Studies, Vol. 7, No.2, pp. 117-124, July 2018, Online ISSN: 2281-4612, Print ISSN: 2281-3993, DOI: 10.2478/ajis-2018-0052.

[29] Prifti, V. Information Data Management in Big Data. Case study: E-Albania Government Portal. *International Scientific Journal "Industry 4.0*", 2022, Vol. 7, No. 3, pp. 87-89, Online ISSN: 2524-997X, Print ISSN: 2534-8582.

[30] Salliu, F. What is the Stage of Development of Albania in the Information Society?. European Journal of Interdisciplinary Studies. May-August 2015, Vol. 1, No. 2, Online ISSN: 2411-4138, Print ISSN: 2411-958X, pp.141-153.

[31] Department of Justice Federal Bureau of Investigation and Cybersecurity & Infrastructure Agency, "Iranian State Actors Conduct Cyber Operations Against the Government of Albania", Joint Cybersecurity Advisory, September 2022, Available at: https://www.ic3.gov/Media/News/2022/220921.pdf, Accessed on October 2022.

[32] ikubINFO Software Engineering, "Government Gateway Platform", Available at: https://ikubinfo.al/government-gateway/, Accessed on October 2022.

Defect detection by frequency analysis of flexural vibrations of free-free composite beam

Yonka Ivanova
Sofia University "St.Kliment Ohridski", Faculty of Physics, Sofia, Bulgaria
Institute of Mechanics at Bulgarian Academy of Sciences, Sofia, Bulgaria
yonivan@phys.uni-sofia.bg, yonka@imbm.bas.bg

Abstract: *This paper presents experimental investigations using a vibration method by impulse excitation of free flexural oscillations of composite beams. The purpose of the study is to establish the sensitivity of the method and technique used for defect detection and localization. To realize the objective, rectangular groove type defects were simulated at different distances and depths. The influence of the location and depth of the artificial cracks on the dynamic properties of the beams was investigated. The resonance frequencies were determined by frequency analysis. A decrease in the resonant frequencies of the flexural oscillations is observed. The experiments conducted show a change in the dynamic characteristics of the beam depending on the dimensions and location of the defects.*
Keywords*: IMPULSE EXCITATION, FREE FLEXURAL OSCILLATIONS, COMPOSITE BEAMS, RECTANGULAR GROOVE TYPE DEFECTS, FREQUENCY ANALYSIS*

1. Introduction

The frequency method is one of the most common methods for detecting delamination and cracks in composite structures by determining the modal shapes and natural frequencies of the structures [1.2.3, 4]. Frequency analysis of composite materials with defects has been developed by researchers [7,8, 9,10] who concluded that the natural frequency of the beam changes in the presence of a defect. Experimental and simulation studies to determine the frequency characteristics and dynamic behavior of composites are published [10,11,12]. The effects of fiber orientation, fiber types, measurement methods, and matrix materials on the dynamic properties of composites were investigated in [6,12]. Frequency analysis of composite plates were conducted by [10,12,13].

From the literature studied, it is seen that a reliable indicator for the detection of defects or damage obtained in service is the change in resonant frequencies. However, unlike modal shape based methods, identification of the location of the damage is not easily achieved when using frequency measurements. Many authors have also studied different types of cracks [13,14]. Important factors influencing fracture behavior and mechanisms are fracture depth and length [2,15].

Pulsed free oscillation excitation is a popular technique for diagnosis of various materials. The earliest research on the subject analysed fundamental frequencies; however, due to measurement errors and noise, natural frequencies in such mode shapes are not sensitive to structural damage [4, 9]. Other approaches have been developed to detect and monitor cracks and damage in various structures – for example, crack growth detection by ultrasonic methods [16].

The presence of a defect leads to a local reduction in the stiffness of the structures, resulting in changes in the dynamic properties, alteration of the natural frequencies, modal shapes and an increase in the damping decrement.

In this work, the applicability of free-bending oscillation methods for the identification of rectangular channel type cracks is investigated. The parameter used to identify the cracks is the natural frequency. The influence of the location and depth of artificial cracks on the dynamic characteristics of composite beams is investigated.

2. Materials and Experimental Procedures

2.1 Materials

A sheet of epoxy fiberglass with a thickness of five millimeters was selected for the study. The plate was fabricated by hot pressing layers of glass fabric impregnated with thermosetting phenolic and epoxy resins. A sufficient number of beam-type specimens were cut from the composite slab with dimensions L=0.25m length, b=0.025m width and h=0.005m thickness. The threads of the glass fabric are parallel and respectively perpendicular to the x-axis /fig.1/.

Fig. 1. Specimen with an artificial rectangular channel type crack

To establish the sensitivity of the pulsed excitation vibration method for defect detection, rectangular groove type defects were simulated at different distances from the edge of the specimens (xi), namely on 0.1L and 0.2L. The dimensionless parameter is used when presenting the results xi /L, The slits are transverse, arranged perpendicular to the stacked layers of glass fabric. The simulated rectangular channels have different depths a=0.2 h and a=0.4 h,. A schematic of the specimens with the artificial defects is given in Fig. 1. A sufficient number of specimens were made and examined to investigate the location of the artificial defects at a fixed defect depth.

2.2 Free Vibration Impact Test

According to the Euler-Bernoulli theory, in flexural transverse vibrations of a beam of constant cross section and thickness, there are innumerable many natural frequencies, which are determined by the dependence:

$$\omega_n = \frac{\pi^2 n^2}{l^2}\sqrt{\frac{EJ_{y\,(z)}}{\rho A}}$$

Where A is the cross section of the beam, $J_{y(z)}$ is the moment of inertia, a characteristic of the cross section, ρ- the density of the material, E is the modulus of elasticity of the composite material. For n=1,2,3,4… the natural frequencies depend on the initial conditions, i.e. the way the oscillations are excited, as well as on the boundary conditions. At n = 1 the beam bends one half wave, at n = 2 there are 2 half waves and so on. The forms of bending oscillations of a beam with free ends are shown in Fig. 2.

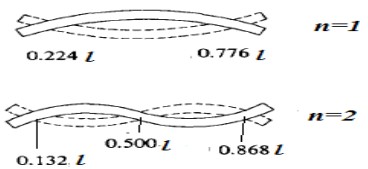


Fig. 2. Shapes of bending oscillations of a beam with free ends

For the fundamental frequency realization at first mode (n=1), the fixed points are at a distance of 0.224 from the ends of the beam. Initially, the fundamental resonant frequency (n = 1) was calculated by the relation:

$$f = \sqrt{\frac{\pi^2 J_y\, E}{4.\rho.A.l^4}}$$

The area of cross-section A is $1{,}25.10^{-4}$ m^2. The moment of inertia is $Jy=2{,}60417^{-10}$ m^4 . The density is $\rho = 1820$ kg/m^3, and the modulus of elasticity E is 20.10^9 Pa

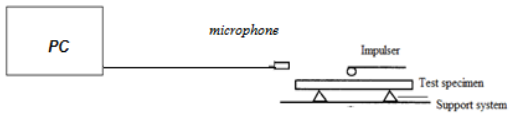
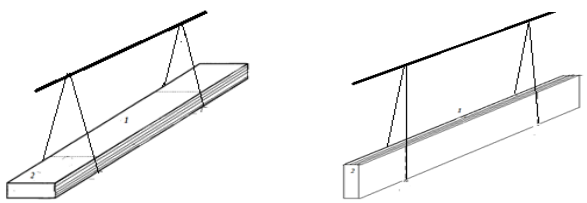


Fig.3. Schematic of experimental setup for the free vibration impact test

A pulse excitation in the middle of the specimen was used to excite transverse bending oscillations in the specimen using a rubber mallet. A Superlux ECM-999 type microphone located at the top of the specimen was used to record the mechanical oscillations. A computer, PC USB 16-bit two-channel sound card 20~20kHz , data logger -Real Time Acoustic Analyzer is used for registration, recording and subsequent signal processing.

The beam was suspended horizontally on elastic rubber strands at two points located at a distance of 0.224 of the length from each end, which are the nodal points for the first mode of flexural oscillations.

To realize "out of plane" bending, in which the direction of displacement is perpendicular to the large plane of the specimen, the diagram in fig. 4a. To excite in-plane oscillations, the scheme given in Figure 4b is used. The microphone is placed close to the specimen above the anti-node point. The specimen is lightly struck in the centre of the specimen. The test is recorded and repeated five times. Five readings of the resonant frequency shall be recorded and the average value taken.



a ***b***

Fig.4. Schematic representation of the beam attachment under excitation of free flexural vibration. a: out of plane flexure; b: in-plane flexure; 1 - impulse point; 2 - microphone point

3. Results and discussion

The test procedure was repeated for different beams made of the same material and geometry, but with different notch locations. The signal obtained from the defective and nondefective beams are compared both in time and spectrum. The natural frequencies and their corresponding amplitudes for the excited first mode of the bending oscillations were obtained.

In Fig. 5 initial results are given for the study of beams bending oscillations out of plane for healthy beams and beams with a defect at distance x=0.1 L. It can be noticed that the presence of a defect leads to a decrease in the natural frequencies of the beams, but this change is negligible.

The offset of the resonant frequency in the presence of a defect is noted by the parameter Δf:

$$\Delta f = \frac{f_{1,o} - f_{1,d}}{f_{1,o}}$$

Where $f_{1,o}$ is the first natural frequency of a healthy beam under excitation of flexural oscillations, and $f_{1,d}$ is the natural frequency of a beam with a crack.

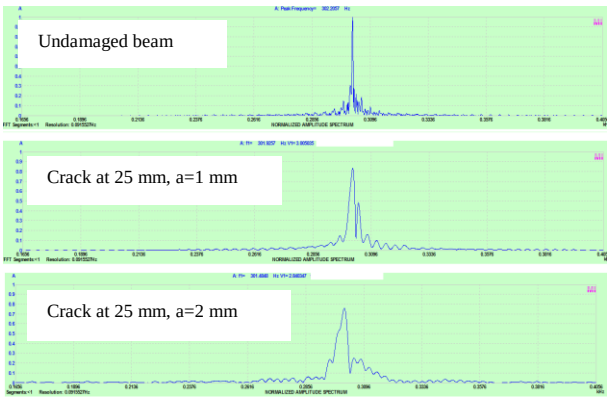
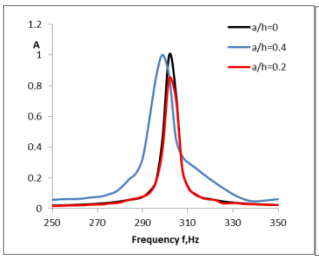


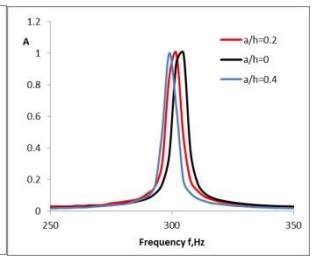
Fig.5. Initial results of the experimental modal analysis of a composite beam with a rectangular channel type crack located at a distance x=0.1 L from the beam origin. /Out of plane vibrations/

From the results given in Table 1, columns 5 , 6 and 7 , 8 respectively, the effect of defects on the values of resonant frequencies of out of plane oscillations and in plane oscillations respectively is observed.

Table 1: Table 1. Results of the experiments for out of plane and in-plane flexure

N	Description	x/L	a/h	1st mode Natural frequency, Hz	Δf,%	1st mode Natural frequency, Hz	Δf,%
				Out of plane flexure		In plane flexure	
1	Undamaged beam	0	0	302.33	0	1443	0
2	defect 0,1 L to the left	0.1	0.2	301.67	-0.2	1440.8	-0.15
3	defect at 0,1 L to the left	0.1	0.4	301.45	-0.3	1447	-0.98
5	without defect	0	0	304.688	0	1426.7	0
6	defect 0,2 L to the left	0.2	0.2	301.44	-1.1	1422.5	-0.28
7	defect 0,2 L to the left	0.2	0.4	299.67	-1.7	1420.7	-0.41





Fast Fourier Transform of the vibration signals for undamaged beams a damaged with notches

Fig.6. x=0.1L with depths a=0.2h,a=0.4h ***Fig.7. x=0.2L with depths a=0.2h,a=0.4h***

For out of plane oscillations, as the distance to the defect increases, i.e., as the parameter x/L is varied by 0.1 and 0.2 for

crack depth a=0.2h, a relative decrease in natural frequency by 0.2% and 1.1%, respectively, is observed. When increasing the depth a= 0.4h, the resonant frequency is reduced to 1.7% . The Fourier spectra of the signals from the investigated beams are given in Figure 6 and Figure 7.

Changes of resonance frequencies in in-plane vibrations in the presence of defects are less than 1% and therefore are not presented graphically. In the process, it was found that the suspension location of the specimens had no noticeable effect due to the large difference between the elastic moduli of the specimens and the suspension strands being on the order of 20.10^3.

3. Conclusion

In this work, the capabilities of the vibration method and the available technique implementation of the method for the identification of defects in epoxy fiberglass composite beams have been investigated and verified. The influence of the ratio of the location of the notches to the length of the beam, as well as the ratio of the splitting of the crack to the thickness of the beam has been investigated. The results show a variation of the dynamic characteristics of the composite beams depending on the dimensions and location of the defects.

Further research is to be carried out to quantify the defect location and the variation of resonance frequencies; and to investigate other types of defects; the anisotropy caused by the location of glass layers in composite beams.

The results obtained do not give any real possibilities for direct practical application of the methodology used. For practical application and realization it is necessary to investigate and systematize the influence of defects on the dynamic properties of beams under excitation of different modes of oscillations.

Acknowledgments:

This work has been accomplished with the financial support by the Grant No BG05M2OP001-1.002-0011-C02 financed by the Science and Education for Smart Growth Operational Program (2014-2020) and co-financed by the European Union through the European structural and Investment funds.

The support of this work through project No. KP- 06KITAJ/3-2020 of Bulgarian research fund is gratefully acknowledged.

References

1. N. Maia et al. Damage detection in structures: From mode shape to frequency response function methods. MSSP **17**(3): 489-498 (2003).
2. E. Manoach et al. Vibration based damage detection in composite beams under temperature variations using Poincaré maps. IJMS, **62**(1): 120-132(2012).
3. E. Manoach et al. Vibration Based Methods For Damage Detection In Structures. MATEC Web Conf. **83** (2016).
4. A. Mohan, S. Poobal. Crack detection using image processing: A critical review and analysis. Alex. Eng. J. **57**(2): 787-798(2018).
5. E. Moustafa. Dynamic Characteristics Study for Surface Composite of AMMNCs Matrix Fabricated by Friction Stir Process. Materials (Basel) **11**(7) (2018).
6. M. Aydın et al. Effect of Orientation Angles on Vibration Properties at Carbon Fiber Reinforced Polymeric Composites. E-Journal of New World Sciences Academy **13**(3): 180-189(2018).
7. S. Iliopoulos et al. Detection and evaluation of cracks in the concrete buffer of the Belgian Nuclear Waste container using combined NDT techniques. Constr Build Mater. **78**: 369-378(2015).
8. D. Ngo-Cong, et al. Free vibration analysis of laminated composite plates based on FSDT using one-dimensional IRBFN method. Comput Struct 89(1): 1-13(2011).
9. G. Pereira et al. Crack Detection in Fibre Reinforced Plastic Structures Using Embedded Fibre Bragg Grating Sensors: Theory, Model Development and Experimental Validation. PloS one **10** (10): e0141495-e0141495(2015).
10. H. Hu et al. Damage detection of surface cracks in composite laminates using modal analysis and strain energy method. Compos. Struct. **74**(4): 399-405 (2006).
11. C. Della and D. Shu. Free vibration analysis of composite beams with overlapping delaminations. Eur J Mech A Solids **24**(3): 491-503 (2005).
12. E. Moustafa et al. Detecting Damage in Carbon Fibre Composites using Numerical Analysis and Vibration Measurements, Lat. Am. J. Solids Struct, **18**(3), e362. (2021)
13. C. Kyriazoglou et al. Vibration damping for crack detection in composite laminates. 'Compos. - A: Appl. Sci. Manuf. **35**(7): 945-953 (2004).
14. J. Yu et al. Studies on Crack Propagation of Carbon Fiber Reinforced Epoxy Resin Composite. Adv. Mater. Res. **79-82**: 1029-1033(2009).
15. F. Iezzi, et al. Experimental Validation of Damage Indices Based on Complex Modes for Damage Detection in Vibrating Structures. *Proceedings of the 13th International Conference on Damage Assessment of Structures, Singapore, Springer Singapore* (2020).
16. J. Wen et al. Damage detection of carbon fiber reinforced polymer composites via electrical resistance measurement. Compos. B. Eng. **42**(1): 77-86 (2011).

Investigation on mechanical properties of Co-Cr-Mo alloy manufactured by selective laser melting

Erdoğan Polat[1,*], İbrahim Etem Saklakoğlu[1]
Department of Mechanical Engineering, Ege University, İzmir, Turkey[1]
erdogan.polat@ege.edu.tr

Abstract: *Additive manufacturing approach is thought to be a key element to meet the needs of Industry 4.0. Selective laser melting (SLM) is a powder bed fusion additive manufacturing method for producing fully functional components. It is critical to determine the fatigue behavior of components produced by selective laser melting in order to fulfill the needs of industries with rigorous norms and criteria, such as the aviation industry. However, the rapid heating and cooling cycle caused by the nature of the SLM process has a negative mechanical effect on the components manufactured by this process.. Mechanical properties such as hardness and fatigue behavior should be disclosed for Co-Cr-Mo alloy manufactured by SLM technique. In this study, hardness and fatigue tests were performed on Co-Cr-Mo alloy components manufactured by SLM, and microstructure images were acquired and evaluated. When the microstructure of the samples was analyzed, tiny precipitates localized at the grain boundaries were discovered, along with the dominating γ phase. The average hardness value of the samples subjected to the Vickers microhardness test was 482±10. The fatigue life of the samples at the maximum stress of 800 MPa was 47,351 cycles. At the minimum stress of 400 MPa, the fatigue life exceeded 10^7 cycles. When fatigue fracture surfaces were examined, flat fracture surfaces similar to semi-cleavage were detected. The results will contribute to the literature on the mechanical characterization of SLM manufactured Co-Cr-Mo alloy components.*

Keywords*: SELECTIVE LASER MELTING, CO-CR-MO, FATIGUE*

1. Introduction

Industry 4.0 encourages the integration of intelligent technology with manufacturing systems. Among these technologies, additive manufacturing is crucial to meet some of the fourth industrial revolution's most pressing needs. Continuous and efficient communication between machines, robots, and devices is essential for additive manufacturing. This is only achievable with the proper digitalization of production processes. As a result, businesses are investing more in digital and IoT, which is a necessity for Industry 4.0.

When compared to traditional subtractive manufacturing technologies, additive manufacturing evolves in the other direction. In contrast to processes like milling or turning, additive manufacturing involves adding the material layer by layer to manufacture components. As a result, it provides less waste and conserves resources and also building prototypes faster, simpler, and less expensive. It produces less waste, conserves resources, and makes prototyping quicker, easier, and less expensive. Other manufacturing processes, such as milling, have high setup and material costs. Because prototyping is less expensive and takes less time, it is feasible to manufacture, test, and make necessary adjustments without too much difficulty. Furthermore, it gives very quick verification of the changes produced.

The simplification of the manufacturing process, particularly product assembly, is another advantage of additive manufacturing in Industry 4.0. Traditional parts are intricate and need several manufacturing stages. Due to this, it now takes more time and cost to manufacture and assemble the various components. However, AM enables you to print the group in a single piece [1].

Additive manufacturing, often known as three-dimensional (3D) printing, has many applications in the industry and is becoming increasingly popular. Additive manufacturing technologies have emerged as a natural result of competitive conditions with the need for rapid prototyping and flexible production. Because of the technological benefits that may be obtained in product design, development, and production processes, this manufacturing method is attracting interest. Additive manufacturing is the subject of research and development studies with increasing interest all over the world due to its advantages such as remote production/prototyping and the production of parts with complex geometries that are not possible with traditional manufacturing method.

Selective laser melting (SLM) is a prominent way for manufacturing Co-Cr-Mo alloy components, and it has become critical to reveal the material's mechanical behavior for this manufacturing process. In a study undertaken for this aim, distinct behaviors in the fatigue behavior of samples manufactured from Co-Cr-Mo alloy material in high cycle fatigue and short cycle fatigue were found as a consequence of topological optimization intended to simulate bone [2]. In a study achieved by Ko et al., it was discovered that there was no significant difference in the fatigue life of the parts in all axes that were held at 1150 °C for one hour among the crochet parts made in different heat treatment and manufacturing orientations [3]. In another study investigating the effect of ceramic coating on the fatigue behavior of Co-Cr-Mo alloy materials produced with different manufacturing techniques, it was determined that Co-Cr-Mo alloy crowns manufactured by selective laser melting showed better fatigue behavior than milled crowns after casting [4]. Due to the large number of internal defects and residual stresses, Razavi et al. reported that components made by selective laser melting exhibit particularly poor fatigue behavior [5]. In a study by Dong et al., the fatigue behavior of samples manufactured by casting and selective laser melting were investigated, and it was discovered that the fine-grained structure and precipitates formed in the parts manufactured by selective laser melting caused secondary cracks reducing stress concentrations and the growth rate of fatigue fractures [6]. In the study by Schweiger et al., traditional casting clamp parts were manufactured by selective laser melting technology, and it was found that the fatigue behavior of the parts was more advanced with reduced volume and homogeneously dispersed pore distribution [7]. Haan et al. employed co-pressure hot pressing to eliminate pores in the components and improve the fatigue behavior of the parts in addition to the selective laser melting approach for knee implant production [8]. In another study exploring the influence of manufacture orientation on fatigue behavior, it was shown that parts made horizontally have superior fatigue behavior than those manufactured vertically [9].

In the selective laser melting method, which is the main subject of this study, manufacturing takes place with a three-stage cycle as shown in Figure 1. In the first stage, with the upward movement of the powder table, which is filled with metal powder, the powder is carried upwards on the ground surface, and then the processing table is moved downwards at the desired layer thickness. In the second stage, the metal powder above the ground of the powder storage tray is swept with the horizontal movement of the powder spreader and the metal powder is laid in the layer space of the processing tray. In the third stage, the desired profile on layer is melted using a laser system. These three procedures are repeated in each layer, resulting in three-dimensional manufacturing.

In this study, the mechanical properties of Co-Cr-Mo alloy which manufactured by selective laser melting was investigated. For this aim, microstructure examinations, hardness measurements and fatigue tests were performed and the obtained results were discussed.

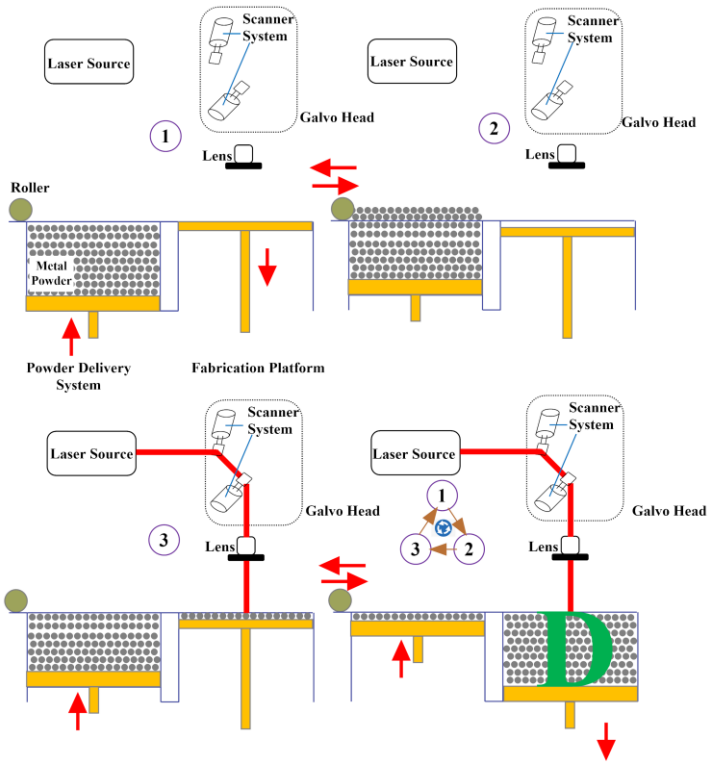


Fig. 1 *SLM manufacturing cycle schematic representation.*

2. Material and methods

Material

In this study, Co-Cr-Mo alloy metal powder named "Puresphere 43055" produced by Sentes-BIR company in Türkiye. The powder shown in Figure 2 was produced in spherical form by gas atomization method.

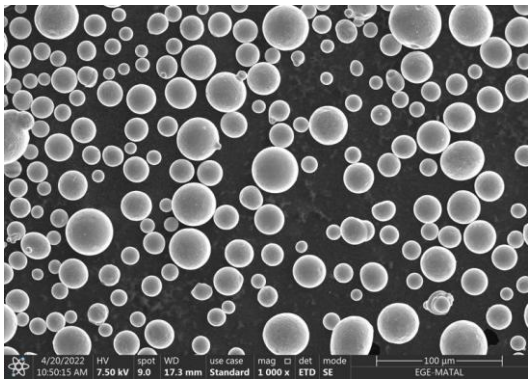


Fig. 2 *SEM image of Co-Cr-Mo metal powder used*

The physical and mechanical properties of the metal powder used are given in Table 1 and its chemical composition is given in Table 2.

Table 1: *Properties of the Co-Cr-Mo alloy used*

Measurement (Unit)	Puresphere 43055
Density (g/cm^3)	8,64
Ultimate strength (MPa)	1285
Yield strength Rp0.2% (MPa)	1085
Elongation at break (%)	9
Youngs modulus (GPa)	200
Hardness (HV)	430±30
Melting range (^{o}C)	1410-1450

Table 2: *Chemical composition of Co-Cr-Mo alloy (% of weight)*

Co	*Cr*	*Mo*	*W*	*Si*	*Mn*
Bal.	*23,3±0,5*	*5,47±0,02*	*5,33±0,07*	*0,89±0,01*	*0,22±0,002*

Specimen preparation

The specimens utilized in the mechanical tests conducted as part of the investigation were manufactured using EOS M290 selective laser melting machine. Specimens were manufactured on the table as cylinders (Ø11mm x 48mm), illustrated in Figure 3, and were removed from the table using the wire erosion process. Samples removed from table were machined for fatigue tests in accordance with the BS ISO 1099:2017 [10] standard, whose geometry is shown in Figure 3.

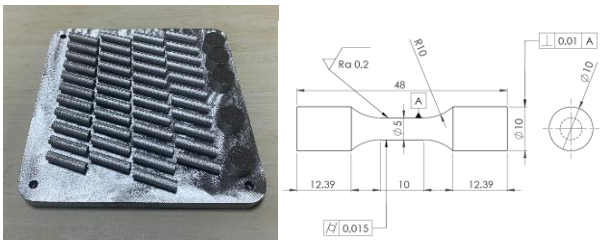


Fig. 3 *Manufactured specimens (left) and fatigue test specimen geometry (right) in accordance with BS ISO 1099:2017 standard* [10]

Microstructural and mechanical characterization methods

The fatigue specimen was cut parallel to the face surface with a low speed diamond cutting tool to observe the microstructure. Then, the samples were molded and sanded using waterproof sandpaper (400-800-1200-2500) and polished with a broadcloth using a 3 micron diamond solution. Electrolytic etching was performed in an H_2SO_4/CH_3OH (5:95) solution with a potential difference of 16-20 V between electrodes. The samples' microstructure was inspected using an optical microscope. The surface roughness measurement instrument Mitutoyo SJ-301 was used to characterize the surface features in accordance with ISO 468:1982 [11]. Hardness tests were performed using a Shimadzu HMV-2 micro Vickers hardness tester in accordance with ASTM E384-17 [12] standard.

Fatigue tests were carried out on Shimadzu EHF-LV020K2-020 fatigue test instrument at 20 Hz frequency values under tensile/tensile constant amplitude loading and R=0.1 stress ratio. Wöhler curves (S-N curves) are used to express fatigue test findings, which are graphs of the stress magnitude and the number of cycles required to cause material deterioration. Fatigue tests were terminated after 10^7 [16] cycles, and the tests were performed in two repetitions at six different stress levels in accordance with ASTM's publication "Manual on statistical planning and analysis for fatigue experiments" [13]. Following the fatigue testing, the fracture surfaces were assessed using a stereo microscope, and comprehensive investigations were carried using a SEM.

3. Results and Discussion

Microstructure and hardness

Figure 4 depicts images obtained with an optical microscope at various scales of the sample manufactured using SLM. The molten pool boundaries were clearly observed in the microstructure images.

A melt pool forms when the laser moves over the powder bed, and the pool grows longer as the laser moves. With rapid solidification of adjacent laser scan traces, cellular melt pool traces typically showed a regular and semi-elliptical appearance. Co-Cr-Mo alloys exhibit ε (hexagonal tight-packed) and γ (surface-centered cubic) structures, according to the literature. [14]. When the phase diagram is analyzed, the ε phase is the low temperature phase and it is seen as the equilibrium phase at room temperature. [15]. As seen in Figure 3, although the γ phase is dominant, there

are small condensed precipitates at the grain boundaries formed during the solidification of the liquid interfaces [16].

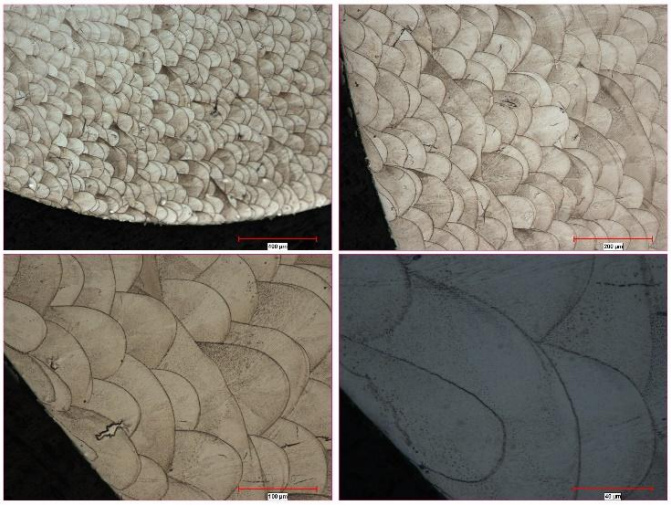


Fig. 4 *Microstructure image of the sample fabricated with SLM*

When the Vickers microhardness values were examined, average hardness values of 482±10 were obtained.

Fatigue

The S-N curves of the Co-Cr-Mo alloy manufactured by selective laser melting are shown in Figure 5. The fatigue life of the specimens (approximately 74% of yield stress) at 800 MPa whic is the maximum stress, was 47,351 cycles. At the minimum stress of 400 MPa, the fatigue life (approximately 37% of the yield stress) exceeded 10^7 cycles.

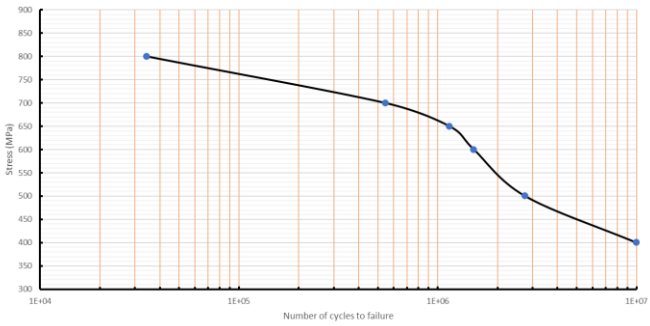


Fig. 6 *S-N curve (average value) of the samples produced by selective laser melting*

The S-N diagram containing the fracture images of the fatigue specimens is shown in Figure 5.

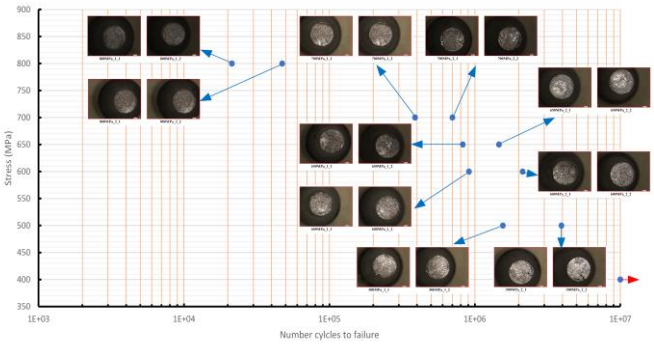


Fig. 6 *S-N diagram with fracture images of fatigue samples*

Figure 7 presents the typical fatigue crack initiation region (7A), crack propagation region (7B), and ultimate fracture region (7C) in fracture images investigating the macro-morphology following the fatigue test. Cracks form lines that propagate forward during a period of the fatigue cycle. In the samples, cracks generally spread from the outer region to the interior region. When the crack propagation region is inspected, it can be seen that the cracks spread radially [17]. There was no obvious evidence of plastic deformation in the crack region, suggesting that a brittle fracture mode predominates during crack initiation and propagation [17].

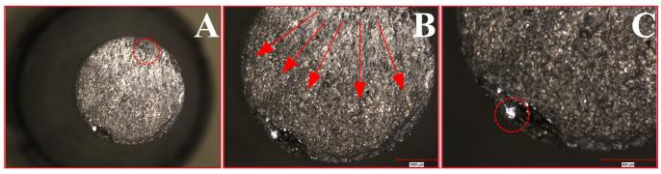


Fig. 7 *The image of the macro fracture morphology of the crack initiation region (A), crack propagation region (B) and final fracture region (C) of the fatigue tested specimen.*

Crack initiation in metals are prone to defects. General internal defects (mostly owing to inadequate melting) were discovered in the fracture images examined after the fatigue test, as illustrated in Figure 8. As shown in Figure 8A, the fatigue fracture morphology was characterized by flat fracture surfaces with a quasi-cleavage (i.e., a fracture that occurs when stress is above a critical level covering a critical area in front of a crack tip and results in a stable fracture) [18]. Similar fracture surfaces were also detected in the other samples. Material fatigue life may be reduced due to the hills seen in Figure 8B and faults caused by inadequate melting depicted in Figure 8C, increasing the likelihood of crack initiation. Unmelted metal powder grain with the size of 21 μm was discovered, as illustrated in Figure 8D. The images of the fracture surfaces acquired were found to be consistent with the literature [19].

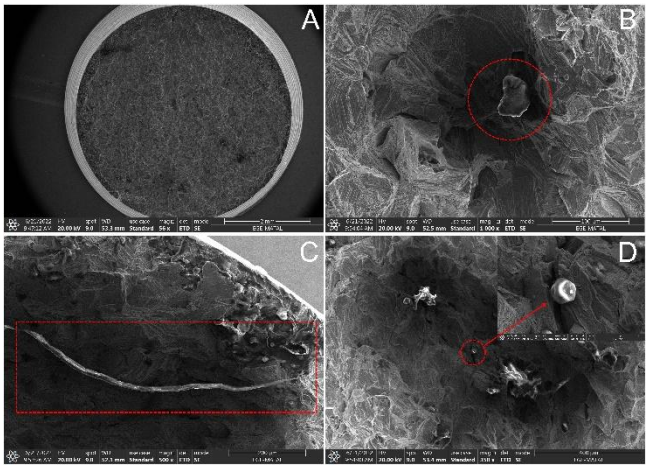


Fig. 8 *SEM image of the fracture morphology of the fatigue tested specimen (A) and general internal defects (B,C,D)*

4. Conclusion

Our study's main goal is to describe the mechanical characteristics of a Co-Cr-Mo alloy manufactured utilizing SLM. The following conclusions can be drawn from the experimental data:

1) When the samples' microstructures are examined, the typical melt pool traces seem semi-elliptical due to the rapid solidification of the adjacent laser scan traces. Despite the fact that γ phase dominates the microstructure, condensed tiny precipitates were seen near the grain boundaries.

2) Vickers microhardness test results showed that the mean hardness value was 482±10.

3) In the fatigue tests, it was observed that the fatigue life was 47,351 cycles at the maximum stress of 800 MPa, and it exceeded 10^7 cycles at the minimum stress of 400 MPa.

4) When fatigue fracture surfaces were inspected, flat fracture surfaces similar to semi-cleavage type fracture were detected. In the samples, cracks generally spread from the outer region to the

interior region. Crack propagation region showed the cracks spread radially.

The data obtained in the study have valuable findings for the mechanical characterization of the Co-Cr-M alloy manufactured with SLM, and will shed light on the studies to be carried out using different parameters (manufacturing parameters, secondary processes, etc.) in this context.

5. Acknowledgments

The samples used in this study were produced by SENTES-BIR in Türkiye. Thank you for their contribution.

6. References

[1] Additive Manufacturing in Industry 4.0. (n.d.). https://www.esa-automation.com/en/additive-manufacturing-in-industry-4-0/ (accessed November 24, 2022).

[2] S.M. Ahmadi, R. Hedayati, Y. Li, K. Lietaert, N. Tümer, A. Fatemi, C.D. Rans, B. Pouran, H. Weinans, A.A. Zadpoor, Fatigue performance of additively manufactured meta-biomaterials: The effects of topology and material type. *Acta Biomater.*, **65**, 292–304, (2018). https://doi.org/10.1016/J.ACTBIO.2017.11.014.

[3] N. Kittikundecha, Y. Kajima, A. Takaichi, H.H. Wai Cho, H.L. Htat, H. Doi, H. Takahashi, T. Hanawa, N. Wakabayashi, Fatigue properties of removable partial denture clasps fabricated by selective laser melting followed by heat treatment. *J. Mech. Behav. Biomed. Mater.*, **98**, 79–89, (2019). https://doi.org/10.1016/J.JMBBM.2019.06.010.

[4] M. Antanasova, A. Kocjan, J. Kovač, B. Žužek, P. Jevnikar, Influence of thermo-mechanical cycling on porcelain bonding to cobalt-chromium and titanium dental alloys fabricated by casting, milling, and selective laser melting. *J. Prosthodont. Res.*, **62**, 184–194, (2018). https://doi.org/10.1016/J.JPOR.2017.08.007.

[5] S.M.J. Razavi, A. Avanzini, G. Cornacchia, L. Giorleo, F. Berto, Effect of heat treatment on fatigue behavior of as-built notched Co-Cr-Mo parts produced by Selective Laser Melting. *Int. J. Fatigue*, **142**, 105926, (2021). https://doi.org/10.1016/j.ijfatigue.2020.105926.

[6] X. Dong, Y. Zhou, Q. Sun, Y. Qu, H. Shi, W. Liu, H. Peng, B. Zhang, S. Xu, J. Yan, N. Li, Fatigue behavior of biomedical Co–Cr–Mo–W alloy fabricated by selective laser melting. *Mater. Sci. Eng. A*, **795**, 140000, (2020). https://doi.org/10.1016/j.msea.2020.140000.

[7] J. Schweiger, J.F. Güth, K.J. Erdelt, D. Edelhoff, O. Schubert, Internal porosities, retentive force, and survival of cobalt–chromium alloy clasps fabricated by selective laser-sintering. *J. Prosthodont. Res.*, **64**, 210–216, (2020). https://doi.org/10.1016/J.JPOR.2019.07.006.

[8] J. Haan, M. Asseln, M. Zivcec, J. Eschweiler, R. Radermacher, C. Broeckmann, Effect of subsequent Hot Isostatic Pressing on mechanical properties of ASTM F75 alloy produced by Selective Laser Melting. *Http://Dx.Doi.Org/10.1179/0032589915Z.000000000236*, **58**, 161–165, (2015). https://doi.org/10.1179/0032589915Z.000000000236.

[9] E. Seki, Y. Kajima, A. Takaichi, N. Kittikundecha, H.H.W. Cho, H.L. Htat, H. Doi, T. Hanawa, N. Wakabayashi, Effect of heat treatment on the microstructure and fatigue strength of CoCrMo alloys fabricated by selective laser melting. *Mater. Lett.*, **245**, 53–56, (2019). https://doi.org/10.1016/j.matlet.2019.02.085.

[10] ISO 1099:2017, ISO 1099-Metallic materials-Fatigue testing, Axial force-controlled methods, 2017.

[11] ISO 468:1982, ISO - ISO 468:1982 - Surface roughness — Parameters, their values and general rules for specifying requirements. (1982). https://www.iso.org/standard/4496.html (accessed September 12, 2021).

[12] E04 Committee, Test Method for Microindentation Hardness of Materials. (n.d.). https://doi.org/10.1520/E0384-22.

[13] R.R. Little, Manual on Statistical Planning and Analysis. *Man. Stat. Plan. Anal.*, (1975). https://doi.org/10.1520/STP588-EB.

[14] M. Zhang, Y. Yang, C. Song, Y. Bai, Z. Xiao, Effect of the heat treatment on corrosion and mechanical properties of CoCrMo alloys manufactured by selective laser melting. *Rapid Prototyp. J.*, **24**, 1235–1244, (2018). https://doi.org/10.1108/RPJ-10-2017-0215/FULL/PDF.

[15] K. Ishida, T. Nishizawa, The Co-Cr (Cobalt-Chromium) system. *Bull. Alloy Phase Diagrams 1990 114*, **11**, 357–370, (1990). https://doi.org/10.1007/BF02843315.

[16] K.G. Prashanth, J. Eckert, Formation of metastable cellular microstructures in selective laser melted alloys. *J. Alloys Compd.*, **707**, 27–34, (2017). https://doi.org/10.1016/J.JALLCOM.2016.12.209.

[17] Q. Shi, Y. Sun, S. Yang, J. Van Dessel, H.T. Lübbers, S. Zhong, Y. Gu, M. Bila, T. Dormaar, J. Schoenaers, C. Politis, Failure analysis of an in-vivo fractured patient-specific Ti6Al4V mandible reconstruction plate fabricated by selective laser melting. *Eng. Fail. Anal.*, **124**, (2021). https://doi.org/10.1016/J.ENGFAILANAL.2021.105353.

[18] B. AlMangour, M. Luqman, D. Grzesiak, H. Al-Harbi, F. Ijaz, Effect of processing parameters on the microstructure and mechanical properties of Co–Cr–Mo alloy fabricated by selective laser melting. *Mater. Sci. Eng. A*, **792**, 139456, (2020). https://doi.org/10.1016/J.MSEA.2020.139456.

[19] Y. Kajima, A. Takaichi, N. Kittikundecha, T. Nakamoto, T. Kimura, N. Nomura, A. Kawasaki, T. Hanawa, H. Takahashi, N. Wakabayashi, Effect of heat-treatment temperature on microstructures and mechanical properties of Co–Cr–Mo alloys fabricated by selective laser melting. *Mater. Sci. Eng. A*, **726**, 21–31, (2018). https://doi.org/10.1016/j.msea.2018.04.048.

Study The Influence of Immersion in The Synthesis of Thin Layers on a Composite Substrates.

M. Aleksandrova[1], V. Petkov[1], V.P. Korzhov[2], I.S.Zheltyakova[2]

[1]Institute of Metal Science, Equipment and Technologies with Hydro- and Aerodynamics Centre "Acad. A. Balevski", Bulgarian Academy of Sciences, Shipchenski Prohod Blvd. 67, 1574 Sofia, Bulgaria, e-mail: mihaela.krasimirova@mail.bg
[2]Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Moscow Region, 142432

Abstract: *Dip coating is a common liquid deposition technique used in research and also for industrial production to produce polymeric, hybrid, and inorganic thin films of controlled thickness. During liquid deposition, the substrate withdrawal rate allows, in principle, easy tuning of the deposited film thickness. However, experimentally, unexplained thickness irreproducibility or strong fluctuations of sol-gel films are often observed when coating large substrates, which is a critical problem for optical coatings such as anti-reflective/reflective coatings. In this study, we present improved coatings obtained by sol gel-like multilayer structures composed of* ZrO_2-Y_2O_3 *coating. The phase composition and morphology were analyzed by X-ray diffraction spectroscopy (XRD), X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) suitable for characterizing the surface properties of the obtained materials*.

Keywords: *DIP-COATING, SOL-GEL, THIN FILMS, MONOLITIC SUBSTRATES*

1. Introduction

Solution dip coating is a widely used method for depositing thin films on various substrates. With this liquid coating process, a homogeneous layer is easily deposited on the surface of the substrate and evaporation of the solvent leads to the formation of a solid film with good control over structure and thickness [1–4]. In principle, both organic and inorganic thin films can be obtained by this method and explored for many applications ranging from electronics [5–8], optical coatings [9], photocatalysis [10, 11] and more [12–14]. Despite the widespread use of sol-gel coatings both in industrial production and in research laboratories, physicochemical phenomena such as location during the coating process are still not fully understood. The first definition of the drain and drag phenomena involved in dip coating was published by Landau and Levich (LL) in 1942 for polymers[15], which built a theoretical model to describe the film formation mechanism and predict the final thickness under certain conditions. Solvent evaporation significantly affects the deposition process, its rate becoming a critical parameter that radically affects the thickness of the deposited film. Capillary mode enables the preparation of thick films with highly dilute solutions at ultralow withdrawal rates and can be used when the deposition species cannot be dissolved or dispersed in high concentrations.[10-15]

The present publication is aimed at the deposition of sol-gel coatings by the dipping method on composite substrates.

2. Experimental part

Eight multi-layer zirconia-yttria protective coating systems were deposited by the sol-gel method on 2 neobium-aluminum alloy substrates. Zirconium-based coatings are obtained from Zr butoxide; $Zr(OC_4H_9)_4$, a small amount of nitric acid was dissolved in 2-propanol. Acetic acid and acetylacetone were added as complexing agents. Finally, 5 wt.% polyethylene glycol added as a structural directing agent is added. The substrates were each immersed in the solution and withdrawn at a speed of 40 mm/min. After each deposition, the samples were sequentially dried at 100°C for 1 hour. The dipping-drying procedure is repeated three times. The deposits were then immersed in a yttrium solution. The final treatment of the samples was carried out at 400°C with a heating rate of 5°C/min.

3. Results and discussion

The phase composition of the samples was investigated by X-ray diffraction (XRD) with CuKα-radiation (Apparatus Philips PW 1050). Chemical composition and morphology were investigated by SEM analyses. X-ray photoelectron spectroscopy (XPS) was applied.

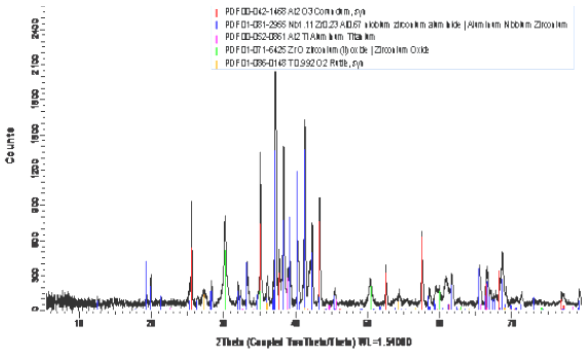
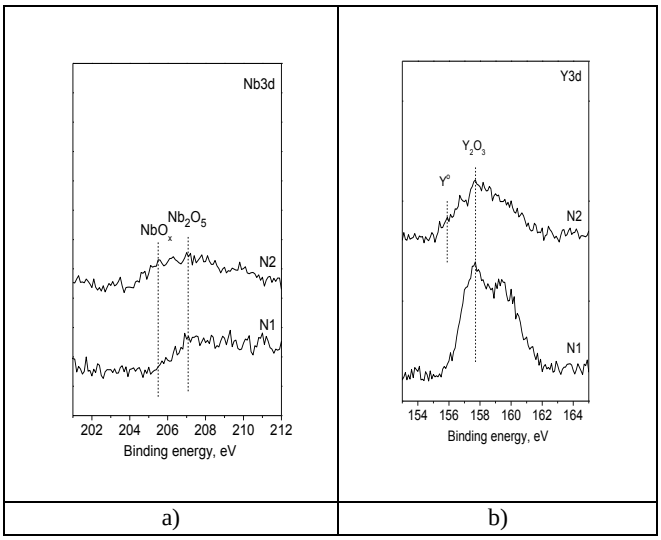
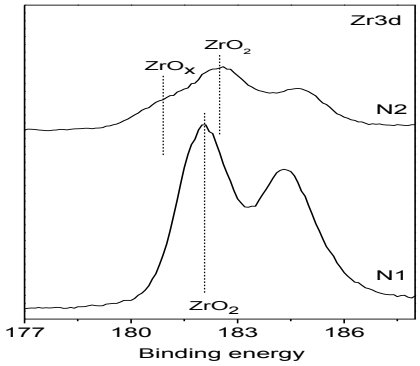


Fig. 1 X-ray diffractogram of deposited layers ZrO_2-Y_2O_3

Figure 1 shows an X-ray diffraction pattern. Angle 2θ varies in the interval 20-80°C. Peaks at approximately 38.5°, 40.1° correspond to $Nb_{1.11}$ ZrO_{23} $Al_{0.67}$ are illustrated.
The peaks at 39.1° and 45.1° show the link between Al_2Ti, while at 31°, 51° and 60° the presence of ZrO_2 is proved. This study proves the deposition of the layer on the substrate despite the non-uniform structure of the substrate.



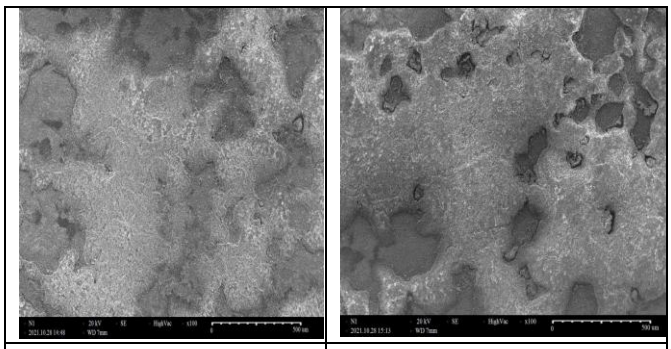


c)

Fig. 2 XPS analysis a),b),c)ZrO_2 modificran s Y_2O_3 prepared by zol-gel method and immersion deposition

The XPS analysis corroborates the results of the X-ray study. XPS spectrum of ZrO_2 modified with Y_2O_3 prepared by zol-gel method and dip deposition on monolithic Nb/Al sample. The sample was found to contain indeed ZrO_2, Y_2O_3 Figure 2(b) and (c). The Y_2O_3 peak at about 158.8 eV for sample N1 is more pronounced compared to sample N2. The second peak at 282.5 eV can be attributed to a characteristic peak for ZrO_2.

SEM (scanning electron microscopy) fig. 3 was conducted on a Scanning Electron Microscope (SEM) is "HIROX SH-5500P" with EDS analysis attachment included "Energy-Dispersive X-Ray Spectroscopy" (EDS) system "QUANTAX 100 Advanced" –Bruker



a)	b)

Fig. 3 SEM images of ZrO_2-Y_2O_3 thin layers

Fig. 3 a) and b) shows SEM images of yttria modified ZrO_2 thin films with eight deposits. It can be observed that these films are not uniform, have very low porosity and not very good adhesion to the substrate. Poor coverage is observed in places, which is due to the fact that the pad does not have a smooth surface. To overcome this problem, when applying the layers, an aging time of about 24 hours will be given, after which the next layer will be applied.

4. Conclusions

A stable sol of ZrO_2 - Y_2O_3 was synthesized and thin films deposited by the dip-coating method. X-ray Diffraction Spectroscopy (XRD), X-ray Photoelectron Spectroscopy (XPS), Scanning Electron Microscopy (SEM) studies were presented to characterize the results, which provided a clear insight into the preparation of the coatings and their deposition on a neo-alumina substrate.

Acknowledgements

The authors are grateful to the financial support of the Bulgarian National Science Fund at the Ministry of Education and Science, Contract No КП-06-Russian/18/15.12.2020.
The work was supported by RFBR grant 50-53-18002.

References:

. 1. Brinker, C. J., Hurd, A. J., Schunk, P. R., Frye, G. C. & Ashley, C. S. Review of Sol-Gel Thin Film Formation. J Non-Cryst Solids 1992, 147, 424–436.

2. Brinker, C. J., Frye, G. C., Hurd, A. J. & Ashley, C. S. Fundamentals of Sol-Gel Dip Coating. Thin Solid Films 1991, 201, 97–108.

3. Brinker, C. J., Lu, Y., Sellinger, A. & Fan, H. Evaporation-Induced Self-Assembly: Nanostructures Made Easy. Adv. Mater. 1999, 11, 579–585.

4. Scriven, L. E. Physics and Applications of Dip-Coating and Spin Coating. in Symposium H - Better Ceramics Through Chemistry III 1988,121, 717-730.

5. Takahashi, Y., Okada, S., Bel Hadj Tahar, R., Nakano, K., Ban, T. & Ohya, Y. DipCoating of ITO Films. J. Non-Cryst. Solids 1997, 218, 129–134.

6. Jang, J., Nam, S., Im, K., Hur, J., Cha, S. N., Kim, J., Son, H. B., Suh, H., Loth, M. A., Anthony, J. E. et al. Highly Crystalline Soluble Acene Crystal Arrays for Organic Transistors: Mechanism of Crystal Growth During Dip-Coating. Adv. Funct. Mater. 2012, 22, 1005–1014.

7. Mirri, F., Ma, A. W. K., Hsu, T. T., Behabtu, N., Eichmann, S., Young, C. C., Tsentalovich, D. E. & Pasquali, M. High-Performance Carbon Nanotube Transparent Conductive Films by Scalable Dip-Coating. ACS Nano 2012, 6, 9737–9744.

8. Valle, G. G., Hammer, P., Pulcinelli, S. H. & Santilli, C. V. Transparent and Conductive ZnO:Al Thin Films Prepared by Sol-Gel Dip-Coating. J. Eur. Ceram. Soc. 2004, 24, 1009– 1013.

9. Cathro, K., Constable, D. & Solaga, T. Silica Low-Reflection Coatings for Collector Covers, by a Dip-Coating Process. Sol. Energy 1984, 32, 573–579.

10. Sonawane, R. ., Hegde, S. . & Dongare, M. . Preparation of Titanium(IV) Oxide Thin Film Photocatalyst by Sol-Gel Dip-Coating. Mater. Chem. Phys. 2003, 77, 744–750.

11. Sonawane, R. ., Kale, B. . & Dongare, M. . Preparation and Photo-Catalytic Activity of Fe/TiO_2 Thin Films Prepared by Sol-Gel Dip-Coating. Mater. Chem. Phys. 2004, 85, 52–57.

12. Lindqvist, K. & Lidén, E. Preparation of Alumina Membranes by Tape Casting and Dip-Coating. J. Eur. Ceram. Soc. 1997, 17, 359–366.

13. Ge, C., Xie, C. & Cai, S. Preparation and Gas-Sensing Properties of Ce-Doped ZnO Thin-Film Sensors by Dip-Coating. Mater. Sci. Eng. B 2007, 137, 53–58.

14. Shieh, J., Feng, H. M., Hon, M. H. & Juang, H. Y. WO_3 and W/Ti/O Thin-Film Gas Sensors Prepared by Sol-Gel Dip-Coating. Sens. Actuators B Chem. 2002, 86, 75–80.

15. Landau, L. & Levich, B. Dragging of a Liquid by a Moving Plate. Acta Physicochim. Urss 1942, 17, 42–54.

Development and Production of Molding Equipment and Plastic masses using new compounding formulations, plastic pressing, drying, high-temperature liquid-phase synthesis and properties of a prototype batch of "yellow" paving stones

Gergana Mutafchieva[1], Lyuben Lakov[1], Mihaela Aleksandrova[1], Marieta Gacheva[1], Gabriel Peev[1], Dimo Mihaylov[1]
Bulgarian Academy of Sciences, Institute of Metal Science, Equipment and Technologies with Hydro- and Aerodynamics Centre "Acad. Angel Balevski"[1], 67 "Shipchenski Prohod" Blvd,
1574 Sofia, Bulgaria, e-mail: cl.creativeline@gmail.com

Abstract: *The research is related to the creation of new compounding formulations for the production of "yellow" paving stones. This was necessary due to denied access to a potential source of suitable raw material from the deposit near the village of Svetlen, Popovo municipality. Marlstone raw material from this deposit has the necessary qualities for such production, as a result of which, after high-temperature liquid-phase synthesis, new petrurgic phases with high physicochemical and mechanical properties can be formed. The new compounding formulation of the molding mass was developed on the basis of marlstone sedimentary rock from the Alexandra deposit, located near the village of Lovets, Targovishte district. The use of this compounding formulation makes it possible to obtain appropriate physicochemical and mechanical properties and a yellow coloring equivalent to that of the reference samples.*
Keywords*: "YELLOW" PAVING STONES, SEDIMENTARY ROCKS, PETRURGIC PHASES*

1. Introduction

The first prototype samples of Bulgarian "yellow" paving stones were made on the basis of marlstone sedimentary rock from a deposit near the village of Svetlen, Popovo municipality [1]. Due to lack of access to this deposit, it was necessary to explore suitable raw materials from alternative sources. For this purpose, marlstone sedimentary rocks from the area of the town of Opaka and the village of Lovets, Targovishte district, were studied. The marlstone sediments from the Alexandra deposit near the village of Lovets showed better results [2]. Based on the preliminary analyzes of the raw material and the laboratory samples of the new compounding formulation, an amount of 1 t plastic mass was prepared, sufficient for the production of 100-200 pieces of paving stones which are identical in shape and size to the standard ones. The stages of implementation of the technological regulation from the starting raw material to the high-temperature liquid-phase synthesis of the finished product are as follows: 1. Study of the chemical and mineral composition of the starting marlstone sediment rock in order to establish the presence of an appropriate proportion of individual oxides and minerals; 2. Preparation of experimental samples with modifying additives to obtain the necessary color and optimization of the temperature mode of the synthesis, as well as examination of the obtained experimental samples; 3. Establishing the indicators necessary for the production of molding equipment, such as compressibility of the mass after synthesis; 4. Production of model and molding equipment for pressing the plastic mass; 5. Preparation of the mass according to the established compounding formulation based on sedimentary rock with modifying additives sufficient to form a prototype batch of "yellow" paving stones [3]; 6. Forming process - pressing of blanks from the plastic mass; 7. Drying of the molded products applying an experimentally tested drying mode; 8. Programming and carrying out a number of experimental temperature modes of liquid-phase synthesis until establishing a suitable one, at which well-baked and fault-free paving stones with the required yellow color are obtained [4,5,6]. The researches include mineral compounds, appropriate glass and mineral phases [7,8,9], suitable modifying aggregates [10], etc.

2. Experiments

According to Step 1, a study was carried out on the chemical composition (Table 1), the mineral phases and their percentage ratio (Table 2), and the results of the differential thermal analysis (DTA) of a sample of the raw material heated to 1,140°C with a heating and cooling rate of 3°C/min and isothermal holding of 80 min (Table 3). It was found that the color was darker than that of the reference samples and that the sintering temperature range was 80±5°C. This necessitated the addition of modifiers to lighten the color and extend the sintering temperature range. For this purpose, samples were made with different percentage ratios of modifying additives such as ZnO, Zr2O, kaolin and raw material based on a sedimentary rock whose color lightens when fired. The ZnO samples did not give the required result as they not only did not lighten the color but darkened it even more and did not widen the sintering temperature range; ZrO_2 lightened the color to the required shade but did not stabilize the sintering temperature; the addition of kaolin gave the necessary color and extended the sintering temperature range, but at the same time it also reduces plasticity, thus hindering the molding process. The best results were obtained from the samples including an additive of clays that lighten when fired, such as clays containing mineral phases kaolinite, quartz and muscovite. The chemical composition of the used modifying clay is shown in Table 4.

Table 1: *Chemical composition of sedimentary rock from the Alexandra deposit, Lovets village, Targovishte district.*

Component	Percentage
SiO_2	35.19
Al_2O_3	11.36
Na_2O	0.7
K_2O	2
MgO	2.24
CaO	19.58
TiO_2	0.47
Fe_2O_3	4.85
MnO	0.11
LOI	23.21

Table 2: *Percentage content of the phases of a fired sample of pure marlstone rock only from the Alexandra deposit, Lovets village, Targovishte region.*

Mineral	%
Chlorite	29
Mica (Muscovite-type)	26
Calcite (Mg-containing)	14
Quartz	13
KFs (potassium feldspar)	8
Plagioclase	6.5
Gypsum	2
Kaolinite	1.5

Table 3: *Percentage content of the phases of a fired sample of pure marlstone rock only from the Alexandra deposit, Lovets village, Targovishte region.*

DTA	From MS – dehydration and decarbonization are observed. There are two carbonate phases: the lower-temperature one corresponds to Mg-containing calcite, the higher-temperature phase is calcite. Concerning weight losses, the amount of carbonate phases is about 22-25% The water probably originates from gypsum and chlorite.

Table 4: *Chemical composition of Ukrainian clay type "Vesko-Prima" that lightens when fired.*

Component	Percentage
SiO_2	63.10
Al_2O_3	31.00
Na_2O	0.30
K_2O	2.10
MgO	0.60
CaO	0.40
TiO_2	1.60
Fe_2O_3	1.00
LOI	8.500

At stage 2, to modify and stabilize the mass, experiments were carried out on test samples with different ratios of chamotte and clay, as well as lightening additives such as ZrO_2, ZnO, kaolin, glass and clay which whitens when fired (Table 5). The best indicators correspond to sample XX with weight parts of clay, chamotte and kaolin of correspondingly 30%, 55% and 15%. This component ratio contributes to achieving good plasticity of the mass, this making it suitable for the molding process of plastic pressing. Residual moisture after vacuum extrusion is 20-25%. The addition of kaolin stabilizes the liquid phase and lightens the mass until a sample corresponding in color to the standard one has been obtained. However, with the addition of kaolin, the mass is still lean, therefore the plasticity is adjusted with the addition of clay that lightens when fired - sample IIa. The mineral phases after synthesis of sample XX (with the addition of kaolin) were studied, and the presence of anorthite, diopside, wollastonite and quartz was established. The mineral phases after synthesis of sample sample IIa (with the addition of clay that lightens when fired) were also studied. Its phase composition is presented in Fig. 1; a DTA was made to establish the temperature mode of sample XX (Fig. 2). The amounts of the modifying additives leading to an equivalent yellow color and high physic-chemical and mechanical indicators were established (Table 5). The mineral composition of the modified samples showed the presence of suitable petrographic phases anorthite and diopside.

Table 5: *Chemical composition of Ukrainian clay type "Vesko-Prima" that lightens when fired.*

Sample	II	III	VI	VII	XX	IIa
Chamotte	55	55	50	50	30	50
Marlstone	40	40	40	40	55	30
ZrO_2	5	-	5	-	-	-
ZnO	-	5	-	5	-	-
SiO_2	-	-	5	5	-	-
Kaolin	-	-	-	-	15	-
Clay type "Vesko-Prima"	-	-	-	-	-	20

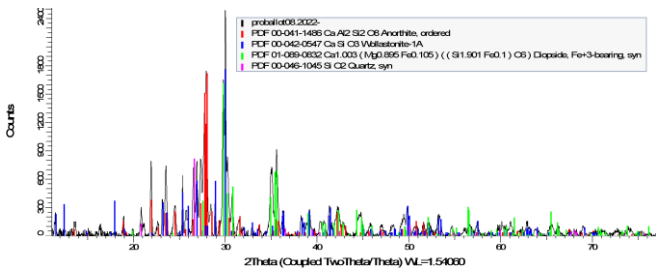


Fig. 1 *Phase analysis of sample IIa with the addition of clay that lightens when fired type "Vesko-Prima", developed in laboratory conditions with the presence of petrographic phases anorthite, diopside, wollastonite and quartz as a result of the modification.*

At stage 3, a firing temperature range of 20-30°C was established, as well as fire shrinkage between 15% and 18%, depending on the humidity of the plastic mass and the sintering temperature. The best results were found for a temperature synthesis at 1130°C, water content in the plastic mass of 20% and fire shrinkage of 17%. A DTA was performed on the modified sample XX with chamotte and kaolin. The analysis indicated several basic steps for sustaining the temperature, on the basis of which experimental modes of high-temperature synthesis were developed (Fig. 2).

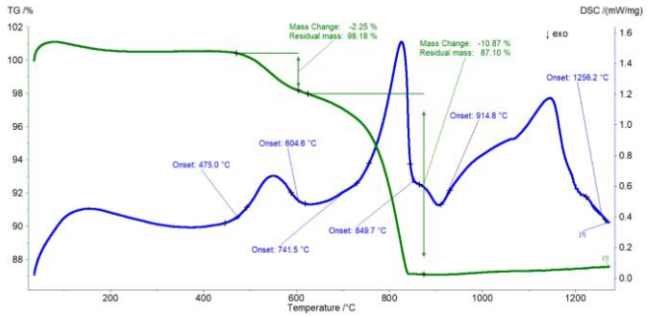


Fig. 2 *DTA of modified sample XX.*

Stage 4 includes the development of model and molding equipment for pressing ceramic blocks of different shape, size and weight, which after sintering acquire a color similar to the "yellow" paving stone standard. Two models were made for molding ceramic blocks with an increase of 17% - a reduced model on a scale of 1:2 and a model in real size. Accordingly, two types of matrix structures were developed for pressing ceramic blocks from plastic mass - one for reduced ceramic blocks (Fig. 4a) and another for block of the original size (Fig. 4b). The two developments differ in their respective constructions as regards their manner of molding, depending on the size of the products. The first one is for pressing reduced-size ceramic blocks and is a metal structure with a mold of polymer modified gypsum mixture that forms the pressing surface. The second is a development for pressing ceramic blocks of the original size and consists of a metal structure and two punches made of composite material which press the mold. Both constructions are proprietary developments and have a number of advantages over traditional matrices, as they reduce the cost of the matrix structure several times compared to an all-metal one. They also have an advantage from the point of view of determining the thickness of the pressed form, adding textures of a decorative and functional nature, etc.

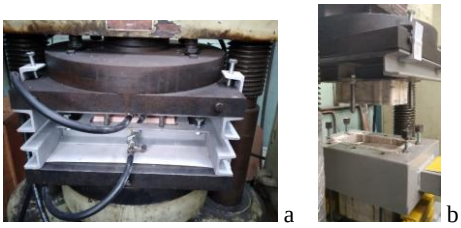


Fig. 4 *View of the installed new matrix structures of the pressing facility: for molding reduced-size blocks in scale of 1:2 (a) and for molding "yellow" paving stones of a shape (b).*

At stage 5, about 1 ton of mass is prepared for the production of a prototype batch of "yellow" paving stones according to the new compounding formulation. For this purpose, the services of external subcontractors were used, as they possess the equipment necessary for obtaining a large amount of mass: a furnace for firing chamotte from marlstone clay, a ball mill for grinding chamotte with a sieve residue below 0.200 mm, a mixer - a ball mill for water grinding and homogenization of a water colloidal dispersion system (slicker), a filter press for removing part of the water content from the slicker, a clay mixer for homogenizing the plastic mass and a vacuum extruder to vacuum the plastic mass. The process of mass preparation is presented in Fig. 5.

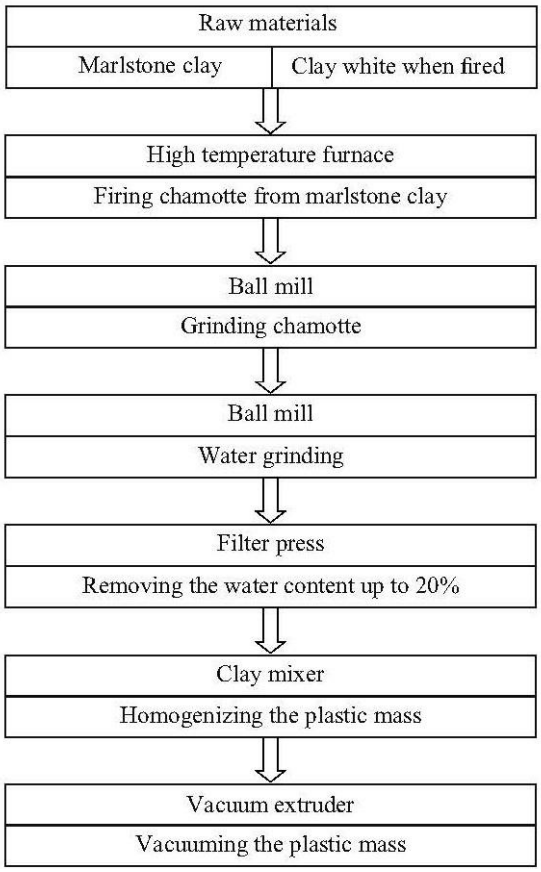


Fig. 5 *Diagram of the preparation of the plastic mass, according to a new compounding formulation, used for the production of a prototype batch of "yellow" paving stones.*

At stage 6, plastic molding is performed. For the reduced-size blocks, the pressing is done using a two-part cast made of polymer modified gypsum. The two parts of the cast split the mold down the middle and form the top and bottom of the product. Separation of the pressed product is done by means of air using a hose installed in both parts of the cast (Fig. 5). With the paving stones of the original size and shape, the process is carried out by pressing the product between two punches. In the metal structure is embedded a negative die, forming the sides of the product, the lower punch forms one front part of the product and presses the mold with a pressure of 13 t/cm^2, and the upper punch sinks 10 mm into the die and forms the other front part of the product (Fig. 6).

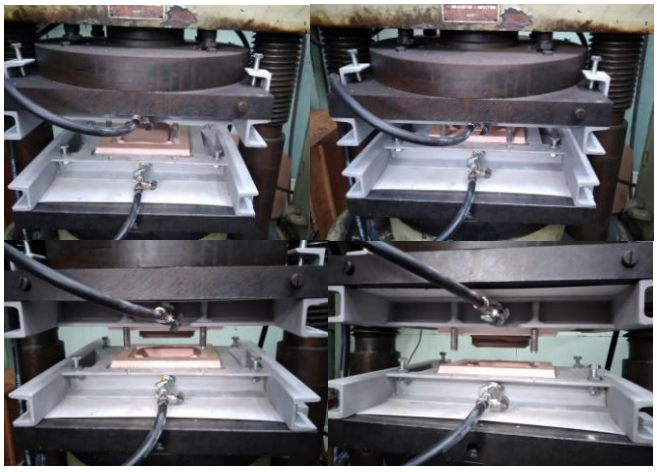


Fig. 6 *Molding process of reduced-size ceramic blocks with the following steps: loading with a the plastic mass blank weighing 680 g, pressing with a pressure of 6 t/cm2, successive release of the two parts of the cast by supplying air with a pressure of 6 bar.*

Fig. 7 *Plastic molding process with the following steps: loading a plastic mass blank with a weight of 5.100 kg, pressing with a pressure of 13 t/cm2, separating the pressed product by pushing it out from the lower punch.*

Stage 7 involves drying. The entire cycle lasts no more than 50 hours with a slow increase in temperature from 0 to 100°C for a gradual removal of the water content from the plastic mass and avoiding deformations and destruction of the structure by thermal shock.

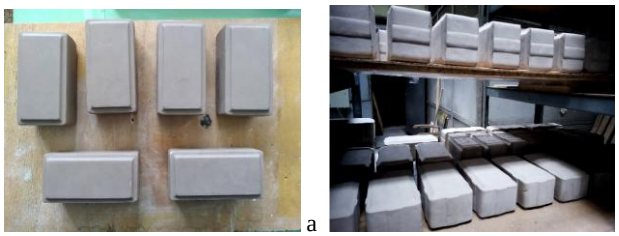


Fig. 8 *Dried blocks ready for high-temperature synthesis: a – reduced (in scale 1:2) ceramic blocks and b – blocks of the same size and shape as the original "yellow" paving stones.*

Stage 8 consist of high-temperature liquid-phase synthesis. Various modes were experimented in order to determine the optimal one. Capsules are made to shield the ceramic blocks in the firing process. It was established that the direct radiation of temperature from the heaters causes defects in the structure and deformations of the products with a larger volume and mass. To avoid this, mullite-quartz ceramic capsules are made to screen the products from all sides. With small paving stones, sintering takes significantly less time, due to their smaller volume and mass, and the above mentioned problems in the firing process are absent.

Table 6: *Temperature mode of experimental high-temperature liquid-phase synthesis in furnace No 1 with ceramic paving stones of a shape, size and weight equivalent to the standard ones.*

Temperature mode in furnace No 1				
Step	Temperature, ^{o}C	Retention time, min	Time to reach the set temperature, min	Total time, h
1	100	480	360	14
2	250	240	240	8
3	650	480	360	14
4	850	480	360	14
5	950	120	360	8
6	1130	480	360	14
Total sintering time, h				72
Note:	A 72-hour temperature regime was carried out; 12 paving stones were placed on a plate smeared with Al_2O_3; the furnace embrasures are opened during cooling.			

Results:	Thermal shock probably occurred when the embrasures were opened; stuck to the refractory plates, as a result of which, when shrunk, all have faults, but are well sintered and of good equivalent colour.

Table 7: *Temperature mode of experimental high-temperature liquid-phase synthesis in furnace No 2 with ceramic paving stones of a shape, size and weight equivalent to the standard ones.*

Temperature mode in furnace No 2				
Step	Temperature, ^oC	Retention time, min	Time to reach the set temperature, min	Total time, h
1	100	480	360	14
2	250	240	240	8
3	650	480	360	14
4	850	480	360	14
5	950	120	360	8
6	1132	480	360	14
7	1030	20	120	2
8	930	20	120	2
9	830	20	120	2
Total sintering time, h				72
Cooling time, h				6
Note:	The samples are screened from above and below and placed on a thin layer of Al_2O_3 powder (with a grain size greater than 120μ); with three steps of cooling; A temperature mode of 72 hours sintering and 6 hours cooling was carried out.			
Results:	Good scrap, well sintered, holds its shape, does not stick, deformed by its own weight on the side it lies on - most likely the temperature is 2-4°C higher.			

Table 8: *Temperature mode of experimental high-temperature liquid-phase synthesis in furnace No 3 with ceramic paving stones of a shape, size and weight equivalent to the standard ones.*

Temperature mode in furnace No 3				
Step	Temperature, ^oC	Retention time, min	Time to reach the set temperature, min	Total time, h
1	100	480	360	14
2	250	240	240	8
3	650	480	360	14
4	850	480	360	14
5	950	120	360	8
6	1128	480	360	14
8	830	20	450	7.5
9	100	5	900	15
Total sintering time, h				72
Cooling time, h				22.5
Note:	2 pcs. shielded from the top, sides and bottom placed on a thin layer of Al_2O_3 powder (with a grain size greater than 120μ); 1 pc located on the side unshielded on a refractory plate sprinkled with a thin layer of the same Al_2O_3 powder.			
Results:	The unscreened sample is cracked at the bottom and with a large deformation; the shielded samples are cracked at the bottom and have a small deformation - they retain their shape, have a good color, are well sintered. Conclusion: To switch to sintering in capsules.			

Table 9: *Temperature mode for sintering of ceramic blocks reduced at a scale of 1:2 compared to the original ones.*

Temperature ^oC	Retention time, min
150	60
650	60
840	180
1140	180

3. Conclusion

The new composition based on marlstone sedimentary rock from the Alexandra deposit, located near the village of Lovets, with added chamotte from the same raw material and clay that lightens when fired, shows good molding capabilities for pressing both reduced-size paving stones, as well as paving stones identical in size, shape and color to the reference ones. The experiments carried out cover a complete process for making a prototype batch of "yellow" paving stones. Additional tests should be done on samples of the newly obtained products, such as X-ray phase analysis, petrographic analysis, structural analysis with computer tomography, tribological tests for wear against various contact bodies, etc.

Acknowledgment

The authors are grateful to the financial support of the Bulgarian National Science Fund at the Ministry of Education and Science, Contract No КП-06-ОПР 03/4 14.12.2018, for carrying out the necessary research

This work was supported by the European Regional Development Fund within the OP "Science and Education for Smart Growth 2014 - 2020", Project CoE "National center of mechatronics and clean technologies", № BG05M2OP001-1.001-0008-C08.

3. References

1. Lakov, L., Encheva, Sv., Tsonev, P., Jivov, B., Aleksandrova, M., Toncheva, K. Production of prototypes of "Yellow paving stones" in Bulgaria Part 1 Physical and Mechanical properties. Journal of Chemical Technology and Metallurgy. Volume 53 Issue 6 (2018)
2. Lakov, L., Mutafchieva, G., Peev, G., Aleksandrova, M., Jivov, B. Physicochemical and technological researches of marls from the area of the village Lovets related to the production of the new "Yellow paving stones". ISJ INDUSTRY 4.0, YEAR VII, Issue 3 (2021)
3. Mutafchieva, G., Lakov, L., Aleksandrova, M., Peev, G. Technology for production of reduced yellow paving stones on the basis of modified marl clay from the Alexandra quarry, the village of Lovets, Bulgaria (Part 1). ISJ MTM. YEAR XVI, ISSUE 3 (2022)
4. Gerasimov E, at all. *Technology of Ceramic Products and Materials*, Edited by Prof. Bachvarov S. (Saraswati press, Sofia 2003)
5. Worrall, W. E. *Ceramic Raw Materials*. London (1982)
6. Štubňa, I., Trník, A., Chmelík, F., Vozár. L. Mechanical Properties of Kaolin-Base Ceramics During Firing. Advances in ceramics - characterization, raw materials, processing, properties, degradation and healing. Croatia (2011)
7. Jivov, B., Dimitriev, Y., Kashchieva, E. Phase Formation in the System $P2O_5$-CaO-ZnO-Ag_2O. Proceedings of the 13th Conference on Glass and Ceramics, 29 September 1 Oktober 1999, Varna, Bulgaria. Vol. 1 (Glass), Varna, Eds B. Samuneva et al. (Publishing House „Science Invest", Sofia, 1999)
8. Jivov, B., Dimitriev, Y., Kashchieva, E. Glass-Crystalline Materials in the System $P2O_5$-CaO-ZnO-Ti". International Journal of Inorganic Materials. 3 (6) (2001)
9. Jivov, B., Dimitriev, Y., Kashchieva, E., Petkov, C. Glasses and Glass Ceramics in the System $P2O_5$-B_2O_3-Ag_2O. Physics and Chemistry of Glasses. 41 (6) (2000)
10. Yakovleva, O. Influence of clay surface composition for structure formation and rheological slip properties. PhD thesis for the award of the educational and scientific degree "Doctor", Institute of New Materials and Technologies, Bibliography 129, 2019, p. 118.

Synthesis and characterization of nanostructured hematite for wastewater treatment

Nadezhda Angelova*, Savina Koleva, Georgi Yordanov
Faculty of Chemistry and Pharmacy, Sofia University St. Kliment Ohridski, Sofia, Bulgaria
nangelovaa@gmail.com

Abstract: *Removal of heavy metals ions from water sources still represents a challenge and different materials are being developed in order to overcome it. Iron oxide nanomaterials receive a lot of attention because of their small size, high surface area, biocompatibility and low cost. However, most of the reported synthesis methods are multi-step and time-consuming. We investigated the co-precipitation method for the synthesis of nanostructured hematite prepared at different temperatures and different calcination times. The obtained materials were characterized by X-ray powder diffraction, scanning electron microscopy and infrared spectroscopy. The adsorption capacity for Pb(II) ions was found to be about 6–12 mg of adsorbed Pb(II) per gram of adsorbent.*
Keywords*: hematite, nanoparticles, nanocrystals, water treatment, microstructure*

1. Introduction

Nanostructured iron oxides have been found suitable for applications in environmental nanotechnology, particularly in wastewater treatment as catalysts, coagulants in flocculation processes and efficient adsorbents for organic wastes and heavy metal ions [1]. Among the various nanostructured iron oxides, hematite (α-Fe_2O_3) nanoparticles have been used for removal of metal ions [2-5], Cr(VI) [6-8], acid dyes [9] and organic carbon [10]. Nanostructured hematite has also been applied for catalytic degradation of organics wastes [6,11-13] and in coagulation and flocculation processes of surface water [14]. These applications are favored by the low toxicity of hematite and the relatively cheap and easy preparation procedures. However, further studies on the methods for preparation of nanostructured hematite are needed in order to find the optimal conditions for production of materials with high adsorption capacity.

Nanostructured hematite is usually prepared by using various modifications of the so-called co-precipitation method [2,5,13,15]. This approach involves precipitation of Fe(III) by alkaline aqueous solutions, followed by washing of the obtained precipitate and its calcination at high temperatures, up to 400–500 °C. Variations in the preparation conditions can result in significant variations in the quality of the final product. In this article we report on the preparation of nanostructured hematite by a modification of the co-precipitation synthesis [2] and studied the effects of calcination temperature and time on the crystallite size and adsorption capacity for Pb(II) ions.

2. Experimental part

Synthesis of hematite. Solution of ammonia (2 M; ~138 ml) was added dropwise to 250 ml 0.1 M ferric chloride (prepared from 6.75 g $FeCl_3.6H_2O$) up to pH 10 upon magnetic stirring (600 rpm) at room temperature. All reagents were of analytical grade. The obtained dispersion was stirred for 2 hours at room temperature and the precipitate was centrifuged (3000 rpm for 10 min), triplicate washed with distilled water to remove soluble salts and let to air dry. The dried substance was calcined in a furnace at different temperatures (200–500 °C) for different time periods (1–4 hours). The calcinated samples were grinded in a mortar before further use.

Characterization of materials. Scanning electron microscopy was performed with Hitachi TM4000 microscope. Samples for SEM were deposited on. double sided duct tape and coated with gold before observation. X-ray powder diffraction (XRD) data were recorded by using a X-ray diffractometer Empyrean (PANalytical) with CuK_α radiation. Fourier transform infrared (FTIR) spectra were measured by using an infrared spectrometer Nicolet 6700 (Thermo Scientific). Samples for FTIR analyses were prepared as KBr tablets.

Adsorption of Pb(II). The tested adsorbent (50 mg) was mixed for 10 minutes with 10 ml 3 mM solution of lead(II) nitrate. The suspension was then filtered through a syringe filter (0.22 µm). The concentrations of Pb(II) in all samples before and after adsorption were determined by standard complexometric titration with 1 mM Na_2EDTA at pH 6 (acetate buffer) and xylenol orange indicator. The adsorbance capacity was expressed as milligrams of adsorbed Pb(II) per gram of adsorbent.

3. Results and discussion

It is known that ferric ions from aqueous solutions are precipitated in alkaline medium as amorphous ferric hydroxide and/or β-ferric oxyhydroxide [16]. Preliminary studies indicated that in the precipitation step of our experiments ferric oxyhydroxide, Fe(O)OH, was obtained with quite small crystallite size of about 3–4 nm. Heating of the dried precipitate at high temperatures (higher than 200 °C) for few hours resulted in the formation of hematite (α-Fe_2O_3) with crystallite sizes of 15–22 nm. Observation by scanning electron microscopy (SEM) showed a powdered material that contained particles of various sizes, from submicron to few micrometers (Fig. 1).

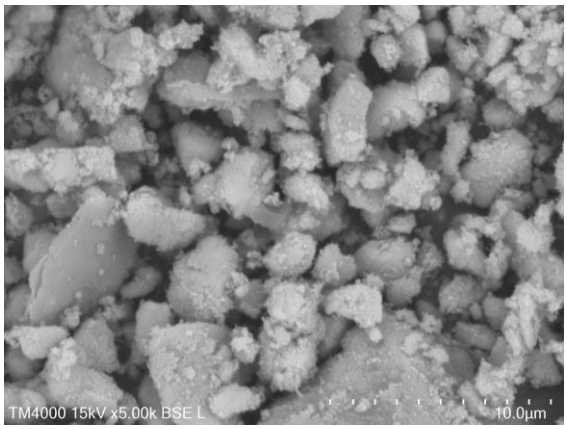


Fig. 1 *SEM image of a hematite sample heated at 400 °C for 2 hours.*

Analysis by infrared (FTIR) spectroscopy showed absorbance peaks for Fe–O bonds at 461 and 536 cm^{-1}, which are characteristic for hematite. Similar FTIR of hematite nanoparticles prepared by the chemical precipitation process were previously obtained, although with a slight different peak positions [17].

XRD diffraction patterns of the samples prepared by heating for 2 hours at different temperatures are shown in Fig. 2. The sample prepared at 200 °C appeared practically amorphous, while those prepared at higher temperatures all contained hematite with average size of crystallites about 15–22 nm. The samples contained also a small amount of amorphous substance. The size of crystallites did not appear to depend significantly on the heating temperature in this particular interval (300–500 °C). Another series of experiments was performed at a constant heating temperature of 400 °C and various heating times. The XRD patterns showed almost identical structure of the obtained hematite phase (Fig. 3).

The experiments on adsorption capacity for Pb(II) ions were performed at relatively high Pb(II) to adsorbent ratio in order to evaluate the maximal adsorption capacity (when the surface of the adsorbent is almost saturated with adsorbed species). The

adsorption capacity of the samples heated for 1–3 hours at 400 °C was about 6–8 mg of Pb(II) per gram adsorbent and did not depend significantly on the heating time (Fig. 4a). The sample heated for 4 hours showed slightly higher adsorption capacity of 12 mg/g. The sample heated for 2 hours at 200 °C showed a similar adsorption capacity of 12 mg/g, while using higher heating temperatures resulted in slightly reduced adsorption capacities of about 8 mg/g (Fig. 4b).

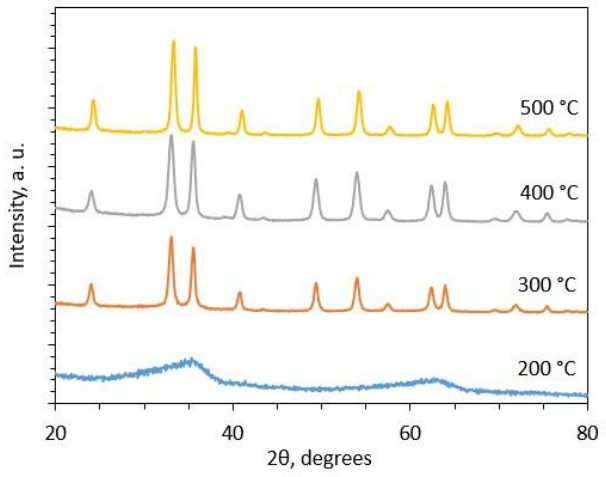


Fig. 2 *XRD patterns of hematite samples prepared by heating at different temperatures for 2 hours.*

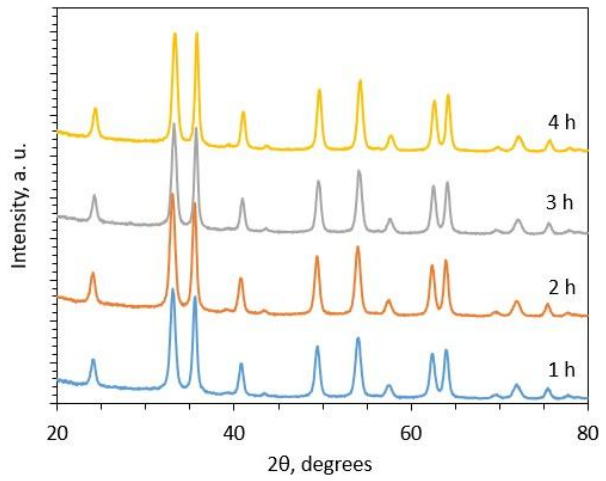


Fig. 3 *XRD patterns of hematite samples prepared by heating at 400 °C for different time.*

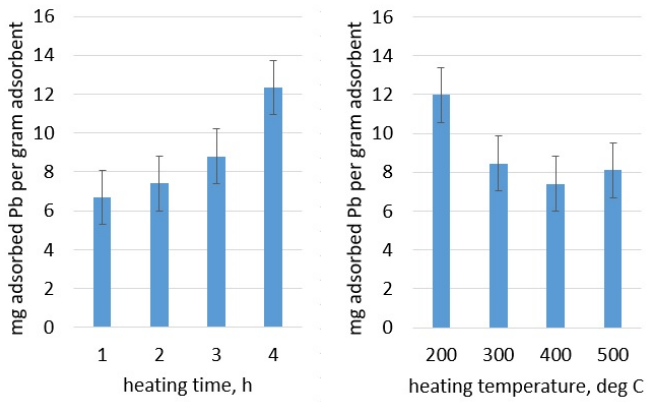


Fig. 4 *Adsorption capacity for Pb(II) of hematite samples prepared by: a) heating at 400 °C for different time; b) heating at different temperatures for 2 hours.*

4. Conclusions

Powder samples of nanostructured hematite were prepared by the co-precipitation, followed by heating at various temperatures (200–500 °C) and time periods (1–4 hours). All samples prepared at temperatures higher than 200 °C contained crystallites of average size about 15–22 nm. The crystallite size and phase composition did not depend significantly on heating time. The obtained materials appeared to be promising candidates for application as adsorbents in wastewater treatment with adsorption capacity for Pb(II) ions within the ranges of 6–12 mg of adsorbed Pb(II) per gram of adsorbent.

.

5. Acknowledgements

The authors are grateful to the Scientific Research Fund of Sofia University, project № 80-10-138/20.05.2022.

6. References

1. K. Jabbar, A. Barzinjy, S. Hamad, Environ. Nanotechnol. Monit. Manag. **17**, 100661 (2022)
2. B. Tsedenbal, J.E. Lee, S.H. Huh, B.H. Koo, C.G. Lee, Korean J. Mater. Res. **30**, 447 (2020)
3. S. Zeng, K. Tang, T. Li, Z. Liang, D. Wang, Y. Wang, W. Zhou, J. Phys. Chem. C **111**, 10217 (2007)
4. A. Saad, A. Azzam, S. El-Wakeel, B. Mostafa, M. Abd El-latif, Egypt. J. Aquat. Biol. Fish. **24**, 13 (2020)
5. K. Kefeni, T. Msagati, T. Nkambule, B Mamba, J. Environ. Chem. Eng. **6**, 1865 (2018)
6. X.L. Fang, C. Chen, M.S. Jin, Q. Kuang, Z.X. Xie, S.Y. Xie, R.B. Huang, L.S. Zheng, J. Mater. Chem. **19**, 6154 (2009)
7. C. Han, J. Xie, C. Deng, D. Zhao, J. Chil. Chem. Soc. **57**, 1372 (2012)
8. J. Li, X. Lai, C. Xing, D. Wang, J. Nanosci. Nanotechnol. **10**, 7707 (2010)
9. D. Dissanayake, M. Mantilaka, T. Palihawadana, G. Chandrakumara, R. De Silva, H. Pitawala, K. Nalin de Silva, G. Amaratunga, RSC Adv. **9**, 21249 (2019)
10. P. Hagare, R. Thiruvenkatachari, H. Ngo, Sep. Sci. Technol. **36**, 2547 (2001)
11. P. Marcinowski, D. Bury, M. Krupa, D. Sciezynska, P. Prabhu, J. Bogacki, Processes 8, 1343 (2020)
12. Z. Liu, X. Zhang, L. Zhao, Adv. Mater. Res. **518-523**, 2414 (2012)
13. H. Mansour, R. Bargougui, C. Autret-Lambert, A. Gadri, S. Ammar, J. Phys. Chem. Solids **114**, 1 (2018)
14. A. Almarasy, S. Azim, E. Ebeid, SN Appl. Sci. **1**, 6 (2019)
15. A. Lassoued, B. Dkhil, A. Gadri, S. Ammar, Results Phys. **7**, 3007 (2017)
16. A. Mackay, Mineral. Mag. **32**, 545 (1960)
17. K. Supattarasakda, K. Petcharoen, T. Permpool, A. Sirivat, W. Lerdwijitjarud, Powder Technol. **249**, 353 (2013)

Emissions to air in a seaport caused by cargo dispersion through the handling operations with dry bulks

Deda Đelović*
Port of Bar, Montenegro
djelovic.deda@gmail.com

Abstract: *After general theoretical introduction referred on port related emissions, in this paper, special focus is given to emission to air in a seaport caused by dispersion of cargo through handling operation with dry bulk cargoes (and their storing on open storage area). In that context, on the concrete object of research – handling operations with dry bulk cargoes in the Port of Bar (Montenegro) – are analyzed elements which determine quantities of dispersed cargoes by handling operations types and their phases, considered intensity of emissions to air caused by cargo dispersion and recognized principal direction of action in order to reduce that dispersion (and consequent emissions to air).*
Keywords*: SEAPORT, HANDLING OPERATION, DRY BULK, DISPERSION*

1. Introduction

Sustainable development of ports has to be based on reliable bases, officially adopted and widely recognized. In that sense, here are systematized some of the principal elements of strategic documents at the European Union level where port sustainable development goals and directions related to emissions to air can be recognized/are defined [1].

Sustainable and Smart Mobility Strategy – putting European transport on track for the future [2]: - the most serious challenge facing the transport sector is to significantly reduce its emissions and become more sustainable; - ports should become multimodal mobility and transport hubs, linking all the relevant modes. This will improve air quality locally thereby contributing to improved health of nearby residents.

The European Green Deal [3]: - The European Green Deal calls for a 90% reduction in greenhouse gas emissions from transport, in order for the EU to become a climate-neutral economy by 2050.

The 2030 Agenda for Sustainable Development [4] - adopted by all United Nations Member States in 2015: at its center are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries. Following SDGs are directly connected with reducing environmental impact of the port area: SDG3- good health and wellbeing, SDG7 – affordable and clean energy, SDG8 – decent work and economic growth, SDG9 – industry, innovation and infrastructure, SDG11 – sustainable cities and communities, SDG12 – responsible consumption and production, SDG13 – climate action, SDG14 – life below water, SDG15 – life on land, SDG17 – partnership for the goal;

The environmental priorities in the European Union ports were changing over the previous years. If the period from 2017 to 2021. is considered [5], than following principal conclusions are clear: - Air quality (AQ) was constantly the first priority; - the biggest advancement (+8) is related to priority Climate changes (CC), from the rank "10" in 2017 to the rank "2" in 2021; - priority Garbage/Port waste fall from the rank "6" in the 2017 to the rank "10" in 2021.

As a result of the rapid growth of international trade, atmospheric pollution from transportation has been more topical than ever, especially in dense hub port-cities [6]. Approximately 230 million people are directly exposed to the emissions in the top 100 world ports in terms of shipping emissions [7]. The higher is the correlated risk of pollution due to higher traffics and related operations [8]. The severity of air quality degradation is all the more serious when taking into account the fact that 90% of European ports are spatially connected to cities [9]. The port emissions can significantly contribute to air quality degradation of urban areas [10].

A typical port layout includes areas dedicated to diverse functions. All of port facilities can be seen as potential sources of pollution, considering elements such as emissions from ships, cars, and other means of transport and correlate with port geographical location, fuel types, energy consumption, road traffic related to the port, and so on [8]. Air pollution emitted from port-related activities can adversely affect the health of port workers, as well as residents of nearby port area, and contribute significantly to regional air pollution problems [11].

2. Categories of pollutant emissions

There are two main categories of maritime polluting emissions: Common Air Contaminants (CAC) and Greenhouse Gases (GHG), plus an additional group if we want to consider other forms of less aggressive pollutants such as dust, smoke, odors, and even noise [7].

There are broad and diverse emissions sources associated with port operations, but not all source types may be found in every port [12].

Emission sources can be organized into two large groups: the first including stationary sources such as warehouses, mechanical plants, offices, portable or emergency generators, electricity consuming equipment, refrigeration/cooling equipment etc., and the latter including mobile sources such as ships, cargo handling equipment that is not designed to operate on public roads, transport vehicles that move goods on public roads, smaller on-road vehicles that transport people and supplies, such as cars and vans, railroad locomotives and so on [7, 12].

Sources can be further divided into emissions source categories within each source group. Another emissions source type related to port operations is unpaved areas used for cargo or equipment storage. Vehicles and equipment moving through these unpaved areas can disturb the soil surface with winds lifting fine dirt particles into the air. These areas are classified as 'area sources' and are usually not included in a port emissions assessment as they are highly variable and difficult to quantify [12].

Cargo handling equipment (CHE) produce more particulate matter (PM) and hydro carbons (HC) emissions than any other emission source in the port. Pollutants from CHE mainly include PM, NOx, HC, COx, SOx, and other emissions that are harmful [13]. Fine particles are a concern because their very tiny size allows them to travel more deeply into lungs and enter the blood stream, increasing the potential for health risks [12].

Dust, in general, can constitute a hazard threatening human health and the environment [8]

3. Reducing emissions to air

In 2013, the European Commission adopted the Clean Air Programme for Europe, with specific measures to achieve the existing air quality targets as soon as possible, and proposals for additional legislation to reduce harmful emissions [14].

The establishment of a balance between economical and ecological interests will be the most important issue for the next decade for all modes of transport, including waterborne transport [15].

Efforts to make maritime transport less polluting must include ports [10]. There is growing pressure at ports around the world to address air pollution generated by cargo movement operations to minimize its impacts on human health and the environment. As

well, there is an increased focus on ports and the maritime industry to reduce emissions to protect public health and the environment [12].

In essence, ports should understand the emissions that arise from their core operations, have an appreciation of the emissions that arise from other maritime activity (such as shipping and cargo operations) in areas under their jurisdiction, and develop responses to these emissions at an appropriate level that reflects their ability to influence the emissions source [16].

There are three key variables that should be considered when designing action – the level of influence a port can have, the time period for the intervention to have effect, and the impact. It is recommended that ports consider the growing range of innovative systems and technologies that provide integrated solutions to facilitate the reduction of emissions, for example use of wind, solar and tidal energy [16].

As modern automated terminals usually achieve high handling efficiency with electric or hybrid equipment, terminal automation is one of the tools to reduce emissions [17].

Many options for air reduction program are available. The selection of the most feasible actions will depend on many factors, such as laws and regulations, terminal set-up, the modal split of the port and the age of diesel engine equipment fleet, etc.[11]. Literature overview on port`s clean air strategies is given in reference [11].

In order to establish bases for adequate implementation of an emissions reductions program, it is necessary to monitor and estimate pollutant emissions in a port. An illustrative example of monitoring campaign conducted is elaborated in details in the reference [18]. Methodology of estimation of air pollutant emissions from ships in port environment and in navigation is developed in the reference [19].

4. A research of emissions to air through handling operations with dry bulks

In this segment of the paper are presented elements of a research conducted in the Port of Bar (Montenegro) related to emissions to air during handling operations with dry bulks, with special focus on emissions to air caused by dispersion of dry bulks through those handling operations.

Principal classes of factors, F_{jk}, which generate emissions to air in the handling operations with dry bulks are (based on [1]):

- F_{1k} - Human factors (improper operating, opening grab at the bigger heights than recommended, ...);
- F_{2k} – Factors related to port infrastructure (problems with power supply, ...);
- F_{3k} – Factors related to port machinery: technical and exploitation performances of port machinery (energy consumption per hour, etc.); port machinery technological adequacy; port machinery downtime frequency; port machinery life cycle phase; etc.;
- F_{4k} – Cargo characteristics (cargo quantity dispersed during the handling operations, ...);
- F_{5k} – Factors related to port warehouses (open and closed);
- F_{6k} – Factors related to system of dust reduction/ elimination; etc.

4.1 Object of research

It is a fact that in the available references are not analyzed enough “area emissions sources” (large open paved areas, dirty roads, unpaved areas) justifying it with their variability and difficulties in their quantification.

Also, results of analyses presented in available references show that intensity of emissions to air in handling operations with dry bulk cargoes is determined by numerous factors, where quantity of dispersed cargo during that handling operations can be recognized as very important.

Dispersed dry bulk cargoes during handling operations is distributed in different directions and, among others, can reach mentioned open areas (open paved areas, roads, unpaved areas) and under influence of port machinery and/or vehicle movements and winds can be emitted to air.

Having all previously mentioned in mind, through this research are investigated elements which the quantity of dispersed dry bulk cargo during handling operations is depending on – all in order to establish bases for assessing emissions caused by dispersed cargo. Directions of reducing quantity of dispersed cargo are defined, too.

Research is done in the cargo handling system in the Port of Bar (Montenegro). Importance rank of the research can be based on throughput structure data for the period from 2017 to 2021 (Table 1), where dry bulk cargoes have the biggest share in overall throughput.

Table 1: *Overall throughput for the period from 2017 to 2021, per cargo groups*

Year	Overall throughput (t)	Dry bulk cargoes		Ro-Ro and general cargoes		Liquid bulk cargoes	
		quantity (t)	share (%)	quantity (t)	share (%)	quantity (t)	share (%)
2017	1,700,204.86	1,349,415.40	79.37	83,181.86	4.89%	267,607.59	15.74
2018	1,382,563.42	1,035,112.00	74.87	67,280.94	4.87%	280,170.48	20.26
2019	1,562,003.91	1,223,176.54	78.31	69,688.55	4.46%	269,138.82	17.23
2020	1,645,542.36	1,380,555.21	83.90	40,834.98	2.48%	224,152.18	13.62
2021	1,457,244.89	1,142,953.56	78.43	49,692.87	3.41%	264,598.46	18.16

(source: Port of Bar, 2022).

In order to complete object of research, with the Table 2 are shown results of an analysis of dry bulk cargoes throughput structure for the period from 2017 to 2021.

Table 2*: Dry bulk cargoes throughput structure for the period from 2017 to 2021*

Dry bulk cargo type	Quantity (t)	Share (%)
Bauxite	2,735,344.30	44.6
Cement	1,070,527.07	17.5
Stone	692,154.75	11.3
Copper concentrate	392,849.36	6.4
Petro-coke	396,724.65	6.4
Iron ore	150,427.00	2.5
Other	693,210.25	11.3
Total	6,131,237.38	100

(source: Port of Bar, 2022).

Finally, object of research can be defined as follows: quantity of dispersed cargo during the handling operations (and storing period on open storage area) with bauxite in the Port of Bar (Montenegro) for the period from 2017 to 2021.

4.2 Objectives of research

Objective of research has following components: defining principal relations for calculating quantities - from the aspects of emissions to air - during the phases of the cargo handling (and storing) process; defining parameters which can be used as bases for estimating emissions intensity during the different phases of the cargo handling (and storing process); identifying factors which intensity of emissions to air during handling operations with bauxite are depending on; calculating quantity of dispersed cargo through the cargo handling (and storing process); identifying directions of reducing dispersed cargo quantity;

4.3 Research methodology

Research is realized using methodology, adjusted to the research object, whose key elements are presented with the Table 3.

***Table 3**: Elements of the methodology*

Phase, PH_i	Expected result, R_j
PH_1: An analysis of parameters which characterize handling operations with bauxite wagon to open storage area and open storage area to ship: quantity of cargo unloaded, quantity of dispersed cargo, quantity of cargo stored, quantity of cargo loaded to ship, cargo quantity emitted to air from wagon, cargo quantity emitted to air from cargo piles (stored cargo), cargo quantity emitted to air from ship holds.	**R_1**: correlations between parameters.
PH_2: An analysis of time intervals and characteristic time moments in the handling operations with bauxite, ranking time intervals as per their duration, estimation of intensity of emissions per operation phases and identifying subjects participating in the logistic chain with dominant influence on recognized time intervals duration, identification of factors which determine intensity of emissions to air.	**R_2:** characteristic time intervals and time moments in the handling process relevant for assessing emissions to air; - ranks of time intervals as per their duration; - identified/estimated intensity level of emissions per handling process phases (operations); - recognized subjects participating in the logistic chain with dominant influence on time interval duration; - defined factors which determine emissions intensity;
PH_3: Data systematization on bauxite quantities handled per operations and in total by months from the period from January 2017 to December 2021.	**R_3**: quantities of bauxite handled per operations and in total by months from the period from January 2017 to December 2021.
PH_4: Calculation of dispersed quantities of bauxite through handling operations by months from the period from January 2017 to December 2021.	**R_4:** dispersed quantities of bauxite through handling operations by months from the period from January 2017 to December 2021.
PH_5: Defining directions of reducing dispersed cargo quantities during handling operations with bauxite (dry bulks).	**R_5:** directions of reducing dispersed cargo quantities through handling operations with bauxite (dry bulks).
PH_6: Creation of a simulation model for assessing emissions intensity to air caused by dispersed cargo through handling operations with dry bulks.	**R_6:** simulation model for assessing emissions intensity to air caused by dispersed cargo through handling operations with dry bulks.

4.4 Research results

Result 1 - Correlations between parameters

In the Table 4 are defined parameters which calculation of dispersed cargo quantity is based on.

***Table 4**: Characteristic parameters*

Wagon	Handling operation
CARGO QUANTITY, Q_{W1} CARGO UNLOADED, Q_{H1} Cargo emitted to air from wagon, q_{w1}	Cargo dispersed, q_{d1}
CARGO QUANTITY, Q_{W2} CARGO UNLOADED, Q_{H2} Cargo emitted to air from wagon, q_{w2}	Cargo dispersed, q_{d2}
..	...
CARGO QUANTITY, Q_{Wn} CARGO UNLOADED, Q_{Hn} Cargo emitted to air from wagon, q_{wn}	Cargo dispersed, q_{dn}

Table 4 - continuation

Open storage area	Handling operation	ship
CARGO STORED, Q_{S1} Cargo emitted to air from cargo piles, q_{s1}	Cargo dispersed, q_{D1}	CARGO LOADED, Q_{L1} Cargo emitted to air from ship holds, q_{S1}
CARGO STORED, Q_{S2} Cargo emitted to air from cargo piles, q_{s2}	Cargo dispersed, q_{D2}	CARGO LOADED, Q_{L2} Cargo emitted to air from ship holds, q_{S2}
	...	
CARGO STORED, Q_{Sn} Cargo emitted to air from cargo piles, q_{sn}	Cargo dispersed, q_{Dn}	CARGO LOADED, Q_{Lm} Cargo emitted to air from ship holds, q_{Sm}

(source: author)

Principal relations which characterize cargo handling process on the relation wagon-open storage are-ship are as follow:

[CARGO QUANTITY (transported to the port with a train), Q_{Wi}] = [CARGO UNLOADED (on the relation wagon to open storage area), Q_{Hi}] + [Cargo emitted to air from wagons, q_{wi} (from the moment when the train is positioned for unloading to its unloading)] (1)

[CARGO STORED (on the open storage area), Q_{Si}] = [CARGO UNLOADED (on the relation wagon to open storage area), Q_{Hi}] – [Cargo dispersed (through the handling operation wagon to open storage area), q_{di}] (2)

[CARGO LOADED (in the ship holds), Q_{Lj}] = [CARGO STORED (on the open storage area), Q_{Sj}] – [Cargo emitted to air from cargo piles, q_{si}] – [Cargo dispersed (through the handling operation open storage area to ship), q_{Dj}] – [Cargo emitted to air from ship holds, q_{Sj}] (3)

Cargo dispersed, $q_{disp.k}$ = [Cargo dispersed (through the handling operation wagon to open storage area), q_{di}] + [Cargo dispersed (through the handling operation open storage area to ship), q_{Dj}] + [Cargo emitted to air from wagon, q_{wi}] + [Cargo emitted to air from cargo piles, q_{sj}] + [Cargo emitted to air from ship holds, q_{Sk}] (4)

Quantity of dispersed cargo can be expressed in following way, too:

Cargo dispersed, $q_{disp.k}$ = quantity emitted to air, q_{eak} + quantity released to water, q_{rwk} + quantity released to soil, q_{rsk} + quantity becoming waste, q_{wk} (5)

Result 2 - characteristic time intervals and time moments in the handling process relevant for assessing emissions to air; ranks of time intervals as per their duration; identified/estimated intensity level of emissions per handling process phases (operations); recognized subjects participating in the logistic chain with dominant influence on time interval duration; defined factors which determine emissions intensity;

In the Table 5 are systematized components of the Result 2.

***Table 5**: Components of the Result 2*

Period of time (PoT)	PoT from the moment loaded wagons enter port zone, t_1, to their positioning at the cargo terminal for unloading, t_2	PoT from the moment of positioning loaded wagons at the cargo terminal for unloading t_2, to beginning of unloading, t_3	PoT from beginning of loaded wagons unloading, t_3, to unloading finishing, t_4	PoT from finishing unloading of wagons, t_4, to the moment of finishing repairing of eventually damaged wagons and hand over of empty wagons between port and railway operator, t_5

Table 5 - continuation

Time intervals	$T_1 = t_2 - t_1$	$T_2 = t_3 - t_2$	$T_3 = t_4 - t_3$	$T_4 = t_5 - t_4$
Ranking of time intervals as per their duration	7	6	3	4
Quantity of cargo	Average quantity per train	Average quantity per train	Average quantity per train	Cargo residues in wagons (after their unloading)
Estimated intensity of emissions	Low	Low	Medium	Very low
Subject with the dominant influence on duration	-Railway operator	-Port operator -Custom forwarder	-Port operator	-Port operator -Railway operator

Table 5 - continuation

Period of staying empty wagons at the cargo terminal – time between the moment of hand over of the empty wagons to the moment of their hauling out of the port zone is beginning, t_6	Period of time from the moment of wagons hauling out of the port zone is beginning to the moment empty wagons leaved port zone, t_7	Period of time from finishing unloading wagons, t_4, to the moment of cargo loading to ship begun, t_8 - Cargo storing time on the open storage area	Period of time from the moment loading of ship started, t_8 to the moment of loading process finishing, t_9
$T_5 = t_6 - t_5$	$T_6 = t_7 - t_6$	$T_7 = t_8 - t_4$	$T_8 = t_9 - t_8$
5	7	1	2
Cargo residues in wagons (after their unloading)	Cargo residues in wagons (after their unloading)	Average stored quantity	Average quantity per ship
Very low	Very low	High	Medium
-Custom forwarder -Railway operator	-Railway operator	-Exporter -Custom forwarder -Port operator	-Port operator -Harbor master office -Shipping agent -Custom Forwarder

(source: author)

Intensity of emissions to air through operations with bauxite (dry bulk cargoes) are depending on:

- cargo characteristics;
- quantity for a period (handled);
- quantity dispersed through handling operations;
- type of cargo handling operations;
- period of exposure (storing period, ...);
- climate characteristics (wind rose, ...);
- implemented handling technology (port machinery, port machinery operaters, stevedores, etc.);
- level of the environmental protection system development (existence of physical barriers, etc.);
- characteristics of the transport means (wagons, trucks, ships); etc.

Result 3 - quantities of bauxite handled per operations and in total by months from the period from January 2017 to December 2021.

In the Table 6 are systematized data on quantities of bauxite handled per operations and in total by months from the period from January 2017 to December 2021.

***Table 6**: Quantities of bauxite handled*

year/ month	wagon- open storage (t)	open storage-ship (t)	difference: stored – delivered (t)	quantity handled (t)
2017/1	72,964.00	19,852.44	53,111.56	92,816.44
2017/2	65,946.00	159,725.78	-93,779.78	225,671.78
2017/3	81,142.00	76,397.36	4,744.64	157,539.36
2017/4	77,024.00	66,076.00	10,948.00	143,100.00
2017/5	69,774.00	97,369.48	-27,595.48	167,143.48
2017/6	70,354.00	0.00	70,354.00	70,354.00
2017/7	49,010.00	94,951.96	-45,941.96	143,961.96
2017/8	69,774.00	74,677.35	-4,903.35	144,451.35
2017/9	66,990.00	75,032.34	-8,042.34	142,022.34
2017/10	82,070.00	98,440.38	-16,370.38	180,510.38
2017/11	66,584.00	21,679.30	44,904.70	88,263.30
2017/12	76,792.00	126,838.55	-50,046.55	203,630.55
2018/1	72,993.80	62,680.00	10,313.80	135,673.80
2018/2	42,960.85	17,394.65	25,566.20	60,355.49
2018/3	32,125.04	80,925.93	-48,800.89	113,050.97
2018/4	18,564.71	0.00	18,564.71	18,564.71
2018/5	26,079.34	0.00	26,079.34	26,079.34
2018/6	7,948.29	63,938.52	-55,990.23	71,886.81
2018/7	14,898.62	0.00	14,898.62	14,898.62
2018/8	10,929.92	0.00	10,929.92	10,929.92
2018/9	16,544.17	0.00	16,544.17	16,544.17
2018/10	29,986.47	77,002.17	-47,015.71	106,988.64
2018/11	19,812.50	0.00	19,812.50	19,812.50
2018/12	45,520.11	66,294.30	-20,774.19	111,814.41
2019/1	29,124.29	0.00	29,124.29	29,124.29
2019/2	25,433.91	0.00	25,433.91	25,433.91
2019/3	42,467.60	74,646.36	-32,178.76	117,113.95
2019/4	46,808.17	0.00	46,808.17	46,808.17
2019/5	45,584.91	64,521.54	-18,936.64	110,106.45
2019/6	47,599.15	76,700.20	-29,101.06	124,299.35
2019/7	41,612.16	0.00	41,612.16	41,612.16
2019/8	38,658.60	28,967.84	9,690.76	67,626.44
2019/9	51,722.16	117,343.58	-65,621.43	169,065.74
2019/10	72,438.94	69,220.61	3,218.33	141,659.54
2019/11	80,671.71	0.00	80,671.71	80,671.71
2019/12	60,784.97	89,501.54	-28,716.58	150,286.51
2020/1	53,862.44	73,847.81	-19,985.37	127,710.24
2020/2	74,294.47	31,454.88	42,839.59	105,749.35
2020/3	79,460.61	62,852.46	16,608.15	142,313.07
2020/4	53,838.41	110,000.00	-56,161.59	163,838.41
2020/5	64,196.19	0.00	64,196.19	64,196.19
2020/6	58,838.23	80,309.43	-21,471.20	139,147.66
2020/7	53,738.88	49,107.58	4,631.30	102,846.46
2020/8	74,105.74	120,044.02	-45,938.28	194,149.76
2020/9	58,828.17	0.00	58,828.17	58,828.17
2020/10	45,358.85	95,718.45	-50,359.60	141,077.30
2020/11	54,075.99	6,966.77	47,109.22	61,042.76
2020/12	46,800.35	88,905.52	-42,105.17	135,705.87
2021/1	28,129.05	4,840.99	23,288.06	32,970.04
2021/2	51,693.81	6,999.08	44,694.73	58,692.89
2021/3	38,734.51	6,100.21	32,634.30	44,834.72
2021/4	3,543.83	46,922.06	-43,378.23	50,465.89
2021/5	31,292.38	47,582.50	-16,290.12	78,874.88
2021/6	35,896.77	45,727.50	-9,830.73	81,624.27
2021/7	25,242.44	0.00	25,242.44	25,242.44

Table 6 - continuation

2021/8	4,660.59	0.00	4,660.59	4,660.59
2021/9	11,224.33	0.00	11,224.33	11,224.33
2021/10	6,283.94	0.00	6,283.94	6,283.94
2021/11	16,444.26	47,434.08	-30,989.82	63,878.34
2021/12	16,431.50	0.00	16,431.50	16,431.50

(source: author based on data from the Port of Bar, 2022).

Result 4 - dispersed cargo quantities of bauxite through handling operations by months from the period from January 2017 to December 2021.

Based on criteria defined in [20] and data given with the Table 6, in the next table (Table 7) are calculated quantities of dispersed cargo through handling operations with bauxite, taking as an initial assumption that dispersed cargo (MC) would be: 0.25%, 0.50%, 0.75% and 1.00% of handled cargo.

***Table 7**: Calculation of dispersed cargo*

year/ month	quantity handled (t)	MC-0.0025	MC-0,0050	MC-0.0075	MC-0.01
2017/1	92,816.44	232.04	464.08	696.12	928.16
2017/2	225,671.78	564.18	1,128.36	1,692.54	2,256.72
2017/3	157,539.36	393.85	787.70	1,181.55	1,575.39
2017/4	143,100.00	357.75	715.50	1,073.25	1,431.00
2017/5	167,143.48	417.86	835.72	1,253.58	1,671.43
2017/6	70,354.00	175.89	351.77	527.66	703.54
2017/7	143,961.96	359.90	719.81	1,079.71	1,439.62
2017/8	144,451.35	361.13	722.26	1,083.39	1,444.51
2017/9	142,022.34	355.06	710.11	1,065.17	1,420.22
2017/10	180,510.38	451.28	902.55	1,353.83	1,805.10
2017/11	88,263.30	220.66	441.32	661.97	882.63
2017/12	203,630.55	509.08	1,018.15	1,527.23	2,036.31
2018/1	135,673.80	339.18	678.37	1,017.55	1,356.74
2018/2	60,355.49	150.89	301.78	452.67	603.55
2018/3	113,050.97	282.63	565.25	847.88	1,130.51
2018/4	18,564.71	46.41	92.82	139.24	185.65
2018/5	26,079.34	65.20	130.40	195.60	260.79
2018/6	71,886.81	179.72	359.43	539.15	718.87
2018/7	14,898.62	37.25	74.49	111.74	148.99
2018/8	10,929.92	27.32	54.65	81.97	109.30
2018/9	16,544.17	41.36	82.72	124.08	165.44
2018/10	106,988.64	267.47	534.94	802.41	1,069.89
2018/11	19,812.50	49.53	99.06	148.59	198.12
2018/12	111,814.41	279.54	559.07	838.61	1,118.14
2019/1	29,124.29	72.81	145.62	218.43	291.24
2019/2	25,433.91	63.58	127.17	190.75	254.34
2019/3	117,113.95	292.78	585.57	878.35	1,171.14
2019/4	46,808.17	117.02	234.04	351.06	468.08
2019/5	110,106.45	275.27	550.53	825.80	1,101.06
2019/6	124,299.35	310.75	621.50	932.25	1,242.99
2019/7	41,612.16	104.03	208.06	312.09	416.12
2019/8	67,626.44	169.07	338.13	507.20	676.26
2019/9	169,065.74	422.66	845.33	1,267.99	1,690.66
2019/10	141,659.54	354.15	708.30	1,062.45	1,416.60
2019/11	80,671.71	201.68	403.36	605.04	806.72
2019/12	150,286.51	375.72	751.43	1,127.15	1,502.87
2020/1	127,710.24	319.28	638.55	957.83	1,277.10
2020/2	105,749.35	264.37	528.75	793.12	1,057.49
2020/3	142,313.07	355.78	711.57	1,067.35	1,423.13
2020/4	163,838.41	409.60	819.19	1,228.79	1,638.38
2020/5	64,196.19	160.49	320.98	481.47	641.96
2020/6	139,147.66	347.87	695.74	1,043.61	1,391.48

Table 7 - continuation

2020/7	102,846.46	257.12	514.23	771.35	1,028.46
2020/8	194,149.76	485.37	970.75	1,456.12	1,941.50
2020/9	58,828.17	147.07	294.14	441.21	588.28
2020/10	141,077.30	352.69	705.39	1,058.08	1,410.77
2020/11	61,042.76	152.61	305.21	457.82	610.43
2020/12	135,705.87	339.26	678.53	1,017.79	1,357.06
2021/1	32,970.04	82.43	164.85	247.28	329.70
2021/2	58,692.89	146.73	293.46	440.20	586.93
2021/3	44,834.72	112.09	224.17	336.26	448.35
2021/4	50,465.89	126.16	252.33	378.49	504.66
2021/5	78,874.88	197.19	394.37	591.56	788.75
2021/6	81,624.27	204.06	408.12	612.18	816.24
2021/7	25,242.44	63.11	126.21	189.32	252.42
2021/8	4,660.59	11.65	23.30	34.95	46.61
2021/9	11,224.33	28.06	56.12	84.18	112.24
2021/10	6,283.94	15.71	31.42	47.13	62.84
2021/11	63,878.34	159.70	319.39	479.09	638.78
2021/12	16,431.50	41.08	82.16	123.24	164.32

(source: author).

Result 5 - directions of reducing dispersed cargo quantities through handling operations with bauxite (dry bulks)

Having in mind character of classes of factors which generate emissions to air through handling operations with dry bulks, as well as, influential factors which the emissions intensity through handling operations with dry bulks is depending on, principal directions of reducing dispersed cargo quantities are:

- optimizing level of used port machinery technological adequacy level, fully respecting demands of the safety on works and environmental protection and results of economical justification of investments needed;
- continuous training of port workers, port machinery operaters and all involved staff to carry out activities fully respecting demand to have minimized quantity of dispersed cargo – warnings on influences which that dispersed cargo cause in domains of health and safety on work, environmental pollution, negative impact on financial parameters, etc.;
- improving system of prevention against dispersing cargo through handling operations with dry bulks: continuous collecting dispersed cargo-cleaning operational area in order to eliminate its further spreading through the port area-forced by winds, movements of vehicles, port machinery, etc.;

4.5 Discussion of results

Dispersion of dry bulk cargo appeared through the operation wagon to open storage area and open storage are to ship as well as a consequence of emissions from wagon, from cargo stored piles and from ship holds. Dispersion of cargo occurs and through other operations with cargo within the port, depending on concrete customer demands, cargo characteristics, disposition of the port facility, etc.

Estimated intensity of emissions per characteristic phases of handling operations wagon – open storage area – ship with dry bulks vary from very law (during the period of staying empty wagons after unloading is finished – from cargo residues in wagons) to high (during the storing period).

Characteristic periods of time during handling operations (wagon – open storage are – ship) depend on different actors participating in the port business (logistic chain).

Quantity of bauxite handled on the relation wagon – open storage area – ship per month ranges from 4,660.99 t (2021/8) to 203,630.55 (2017/12). Respecting a fact that cargo quantity handled is one of the factors with direct influence on emissions to air, it is clear that intensity of emissions is proportional to cargo quantity handled.

Under assumption that percentage of dispersed cargo is 0.25% of quantity handled per month, than estimated dispersed cargo quantity ranges from 11.65 t to 509.08 t. When the assumed percentage of dispersed cargo is 0.50% of handled cargo, than quantities of dispersed cargo per month vary from 23 t to 1,018.15 t, if the percentage of dispersed cargo is 0.75% of total quantity handled, than estimated quantities are within the range from 34.95 t to 1,527.21 t and for the variant of 1.00%, quantities of dispersed cargo are from 46.62 t to 2,036.31 t. Calculated values of dispersed cargo quantity per month clearly confirm a need for adequate treating this issue and for having an adequate management system in this domain in order to carry out all preventive and corrective actions on time, thus avoiding potential negative impacts. At the same time, by the approach proposed in this paper are established bases for assessing emissions caused by dispersed cargo through handling operations with dry bulk cargoes.

5. Conclusions

In general, considerations (and related research) given in this paper are more relevant for the ports with variations in cargo throughput structure over the period and in situation when investments in specialized facilities for handling operations with dry bulks are not justified from the aspect of cargo volume or financial parameters (investment capability of a port, …).

All issues treated by the paper became more critical in case of powder cargo handled by port machinery with grabs and in case when more handling operations are needed, transport paths within the port are longer, etc.

Author intend to continue work related to the topic treated with this paper, having as an objective to come to the simulation model for assessing emissions intensity to air caused by dispersed cargo through handling operations with dry bulks.

6. References

1. D. Delovic, Some considerations on correlation between port equipment maintenance and environmental aspects, International Conferences on Science and Technology, INCOST EST 2022 (ee-book, to be published), Budva (2022).
2. European Commission, COM/2020/789 final Sustainable and Smart Mobility Strategy, https://eur-lex.europa.eu (2020)
3. European Commission, COM/2019/640 final European Green Deal, https://ec.europe.eu/ (2019)
4. Sustainable Development Goals, https://sdgs.un.org (2015)
5. M. Puig, C. Woolridge, R. M. Dabra, ESPO Environmental report, ECOPorts insights, European Sea Port Organization (2021)
6. L. Hyangsook, T. P. Hoang, C. Maowei, C. Sangho**,** Bottom-Up Approach Ship Emission Inventory in Port of Incheon Based on VTS Data, Ad. Data Intel. Th. And Pract. in Trans., Vol. 2021, Article ID 5568777, https://doi.org/10.1155/2021/5568777 (2021)
7. O. Merk, Shipping Emissions in Ports, OECD, International Transport Forum, Paris, https://www.itf-oecd.org/ (2014)
8. S. Barberi, M. Sambito, L. Neduzha, A. Severino, Pollutant Emissions in Ports: A Comprehensive Review. Infrast. 2021, 6, 114. https://doi.org/10.3390/ infrastructures6080114 (2021)
9. F. Bojic, A. Gudelj, R. Bošnjak, Port-Related Shipping Gas Emissions—A Syst. Rev. of Res. Appl. Sci. 2022, 12, 3603. https://doi.org/10.3390/app12073603 (2022)
10. V. Knežević, Z. Pavin, J. Čulin, Estimating Shipping Emissions – A Case Study for Cargo Port of Zadar, Croatia, the Int. J. on Mar. Nav. and Saf. of Sea Trans., Vol. 15, No. 3, (2021)
11. C. H. Han, Air Pollution Reduction Strategies of World Major Ports, The Inter. Com. & Law Rev., Vol. 48 (2010).
12. GEF-UNDP-IMO GloMEEP Project and IAPH, Port Emissions Toolkit, Guide No.1, Assessment of port emissions (2018)
13. Y. Zhang, Y. Peng, W. Wang, J. Gu, X. Wu, X. Feng, Air emission inventory of container ports' cargo handling equipment with activity-based ''bottom-up'' method, Adv. in Mech. Eng. Vol. 9(7) (2017)
14. J. Cofala, M. Amann, J. Borken-Kleefeld, A. Gomez-Sanabria, C. Heyes, G. Kiesewetter, R. Sander, W. Schoepp, M. Holland, H. Fagerli, A. Nyiri, Final Report The potential for cost-effective air emission reductions from international shipping through designation of further Emission Control Areas in EU waters with focus on the Mediterranean Sea, IIASA, Austria
15. C. Trozzi, R. Vaccaro, Environmental impact of port activities, Maritime Engineering and Ports II, C.A. Brebbia & J. Olivella (Editors), www.witpress.com (2000)
16. Port Air Quality Strategies, Department for Transport, London, www.gov.uk/dft (2019)
17. S. Narusu, IAPH'S Initiatives to reduce emissions from ports, Multi-year Expert Meeting on Transport, Trade Logistics and Trade Facilitation Sustainable Freight Transport Systems: Opportunities for Developing Countries, International Association of Ports and Harbors (IAPH) (2015)
18. F. Quaranta, F. Murena, M.V. Prati, Assessment of the impact of ship emissions on the air quality in Naples, Maritime Transportation and Harvesting of Sea Resources – Guedes Soares & Teixeira, Taylor & Francis Group, London (2018)
19. C. Trozzi, R. Vaccaro, Air Pollutant Emissions from ships: high Tyrrhenian Sea ports case study, Trans, on the Built Env., vol 36 (1998)
20. Tarifa usluga i naknada u međunarodnom transprotu roba, Opšte tarifne odredbe, Luka Bar (2002)

Production engineering curriculum in the context of Industry 4.0 – current state of art and necessary changes in AP of Vojvodina and Republic of Srpska

Milenko Sekulic[1,*], Mijodrag Milosevic[1], Stevo Borojevic[2], Branislav Sredanovic[2], Andjelko Aleksic[1], Jovica Ilic[2]
University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia[1]
University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, Bosnia and Herzegovina[2]
milenkos@uns.ac.rs

Abstract: *Industry 4.0 (I4.0) provides the framework for a new industrial revolution based on digitalization and networking. This production concept is based on the intelligent connection of mechanical engineering, electronics and software. The development of the I4.0 concept has directly contributed to the development of new technologies and business models as well as new ways of working and thinking. The implementation of Industry 4.0 technologies in the education of engineers is a basic prerequisite for the development of the economy and society. For this reason, university education of production engineers must constantly change and adapt to modern production technologies and systems. The widespread application of new technologies in production practise requires a rapid response from the university community, which is reflected in the introduction of innovations in the traditional education of production engineers. The paper analyses the current curriculum of production engineering studies at the Faculty of Technical Sciences in Novi Sad (Republic of Serbia, AP of Vojvodina) and the Faculty of Mechanical Engineering in Banja Luka (Bosnia and Herzegovina, Republic of Srpska) in terms of the requirements and needs of Industry 4.0. Based on the analysis, proposals and guidelines for their innovation were given.*

Keywords*: PRODUCTION ENGINEERING CURRICULUM, INDUSTRY 4.0, STATE OF ART, NECESSARY CHANGES*

1. Introduction

By implementing the concept of Industry 4.0 in production, employers will demand new skills and abilities from their employees. The implementation of this concept in manufacturing will have a positive impact on companies in Serbia and Bosnia and Herzegovina by enabling: an increase in the competitiveness of companies, greater flexibility in production, an increase in productivity and ultimately an increase in their profitability. The impact of the I4.0 concept on occupational health and safety and the environment should not be neglected either. For this reason, teaching and training techniques must be changed, especially at universities that train production engineers.

In the last decade, a large number of papers have been published on the topic of education in the context of Industry 4.0. In these papers, the focus is on different areas, such as: new qualification requirements, new subject areas that should be included in curriculum, the transformation of education itself (Education 4.0), and the development of new laboratory concepts that would bring students closer to the Industry 4.0 production environment.

The general conclusion is that the new industrial practice reminds us every day that education as we know it today must significantly change its character. The workforce of the future will have to work with big data. They will need to be able to quickly find the information they need and then put it into practice. Communication technologies are bringing rapid change, so the answer to the question of how and in what way to educate the engineers of the future is by no means easy or simple. The main objective of this work is to determine the current state of art of production engineering curricula at the University of Novi Sad and the University of Banja Luka, in order to identify the areas on which the content of engineering education should be focused in the future with regard to the concept of Industry 4.0 (I4.0).

The University of Novi Sad, i.e. the Faculty of Technical Sciences (acronym: UNS-FTS), is the engine of industrial development in AP Vojvodina and the Republic of Serbia. On the other hand, the University of Banja Luka and its Faculty of Mechanical Engineering (acronym: UBL-FME) are the carriers of the development of the Republic of Srpska and Bosnia and Herzegovina. AP Vojvodina and Republika Srpska have a very well developed cultural, educational and scientific cooperation. This paper is the result of joint research by colleagues from these two universities within the project entitled: "The impact of the Industry 4.0 concept on the transformation of modern university engineering education in AP of Vojvodina and Republic of Srpska", and has been supported by the Provincial Secretariat for Higher Education and Scientific Research AP of Vojvodina.

2. Competencies and skills for Industry 4.0

The term Industry 4.0 can be explained by different concepts, such as smart factory, cyber-physical systems, self-organization and adaptation to human needs [1]. The final goal of the I4.0 concept is the creation of smart factories, where there will be autonomous systems with the possibility of self-configuration and self-monitoring. The new production processes will be based on collaboration between humans and machines. This collaboration will not be possible without the application and integration of the following technologies in practice, Fig. 1: Robotics, IoT, Additive Manufacturing, Virtual (VR) and Augmented Reality (AR), Simulation, Systems Integration, Big Data, Artificial Intelligence, Industrial Security, CPSs, Mobile and Wearable devices, and Cloud Computing. The Industry 4.0 model promotes the connection of physical components such as sensors, devices and machines, both to each other and to the Internet.

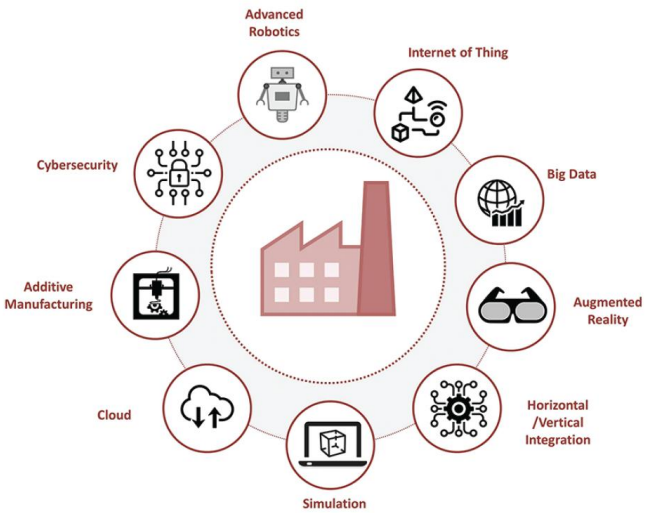


Fig. 1 *Industry 4.0 technologies [2]*

Figure 2 shows the new skills and competencies that Industry 4.0 requires from workers, as well as their integration and importance depending on. These skills can be divided into: ***technical, methodological, social and personal***. Each of these skills has a corresponding importance, depending on the employee's role in the company. It is obvious that, for example, technical workforce must have a good knowledge of equipment, process and production technologies. Production engineers and managers of production

facilities, of course, must have the necessary knowledge for a methodological approach, creativity, problem solving, decision making, and analysis and research skills. Their social and personal skills (communication, cooperation, leadership, autonomy, flexibility and responsibility) are no less important than technical and methodological skills. The new technological world will require people who can make quick decisions based on the information available to them. The amount of intangible work will increase with digitization, robotization, artificial intelligence, and the Internet of Things, so the human skills of sharing ideas and thinking critically will become increasingly important. Based on the above facts, the current educational system should be transformed in the following main directions: incorporating technical multidisciplinarity into the curriculum, incorporating non-technical courses into the curriculum, offering problem-based learning, updating teacher skills, promoting innovation in teaching, organizing collective training programs and apprenticeships, accepting the concept of lifelong learning [4].

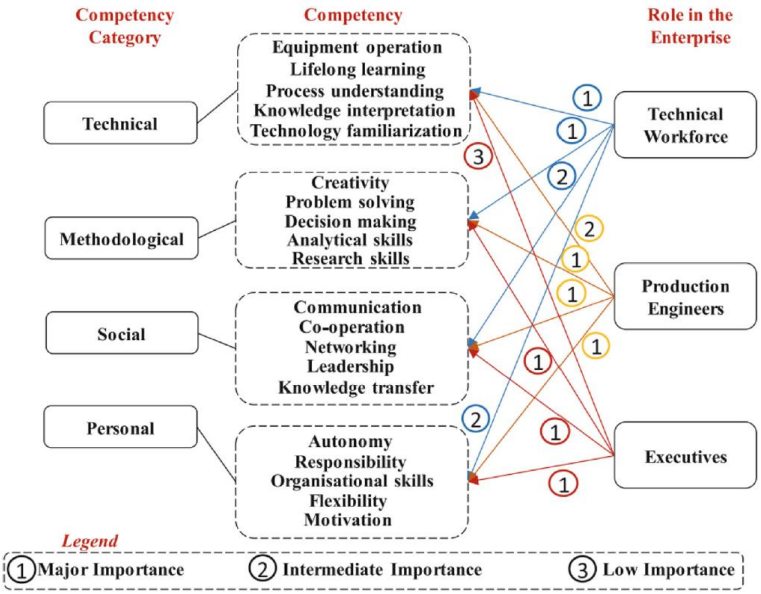


Fig. 2 *Industry 4.0 competencies and their importance for perfoming roles in the company [3]*

Technical competencies in the context Industry 4.0

The European Union - funded project entitled "The Universities of the Future" has identified the technical competencies that the engineers of the future should possess. These competencies are listed in the Table 1, and divided into the areas of engineering, business and design [6].

Table 1: *Mechanical Engineering, Business and Design Elements of I4.0*

Engineering Competencies	Business Competencies	Design Competencies
Data Science and advanced (Big Data) analysis	Technology awareness	Understanding the impact of technology
Novel human-machine interfaces	Change management and strategy	Human-robot interaction and user interfaces
Digital-to-physical transfer, technologies, such as 3D printing	Novel talent management strategies	Tech-enabled product and service design
Advanced simulation and virtual plant modeling	Organizational structures and knowledge	Tech-enabled ergonomic solutions and user experience
Data communication and networks and system automation	The role of managers as facilitators	
Artificial Intelligence	Tech-enabled processes: Forecasting and planning metrics, scheduling	
Robotics		
Programming skills		
Closed-loop integrated product and process quality control/management systems		
Real-time inventory and logistics optimization systems		

Advanced manufacturing technologies are an important factor that will lead society to higher industrial competitiveness, sustainable growth and job creation. The number of high-skilled manufacturing jobs will increase in the near future. The growing demand for higher-skilled workers includes those with traditional engineering profiles - process engineers, quality control engineers, mechanical or mechatronics engineers. At the same time, there will also be demand for newer skills - particularly designers, industrial data scientists, 'Big Data' statisticians/mathematicians and data security analysts. The most in-demand profile is likely to involve a combination of engineering and information and communications skills.

3. Production engineer profile in Industry 4.0

The production engineer is a professional capable of performing a range of activities within industrial manufacturing methods and production lines, as well as other related services. These activities include coordination, planning, feasibility studies, technical services, audits, research and teaching, budget preparation, and quality monitoring. However, with the advent of Industry 4.0 and the associated digitalization, these definitions need to be revised and updated. The classic profile of engineers' work will increasingly have to dive into the world of information and communication technology to deal with the modelling of processes and complex systems [7]. It is fair to ask whether the production engineers graduating today will be able to perform the tasks that Industry 4.0 and the new digital environment will demand of them. Classical teaching methods based only on lectures will not be sufficient to develop the necessary skills for future production environments. Numerous publications on the topic of education in the context of Industry 4.0 propose the development of new laboratory concepts

that enable students to experience a production environment like that of Industry 4.0 [8].

In Industry 4.0 tasks will be complex and require collaboration with machines [9]. Production engineers will be tasked with the following in Industry 4.0 [4]: ***pre-production & planning*** (research & development and product design; resource planning & procurement; staff augmentation & management), ***production & logistics*** (machining, production & assembly; supply chain management; warehousing & transportation), ***monitoring & control*** (operations, maintenance & continuous improvement; quality, risk & compliance; health, safety & environment), ***new paradigms*** (cybersecurity; product service systems; sustainability & circular economy). Industry involvement in education and training is seen as a key element in ensuring that production engineers are trained for the skills required by Industry 4.0.

The new profile of a production engineer in Industry 4.0 should be based on the following five pillars [4] : ***basic technical knowledge*** in the field of production engineering; ***methodological skills*** such as process-related and systemic thinking; ***basic cross-disciplinary knowledge*** in the fields of mechanical engineering, electrical engineering and electronics, as well as data science for computer science; ***contextual knowledge***, i.e. knowledge of the conditions, requirements and perspectives in other fields and disciplines; and ***interdisciplinary skills***, in particular the ability to work in a team, independence, motivation, problem-solving skills, the ability to learn and adapt, openness and communication skills.

Figure 3 shows the pillars on which the new profile of a production engineer is based and the tasks that this engineer will perform in Industry 4.0.

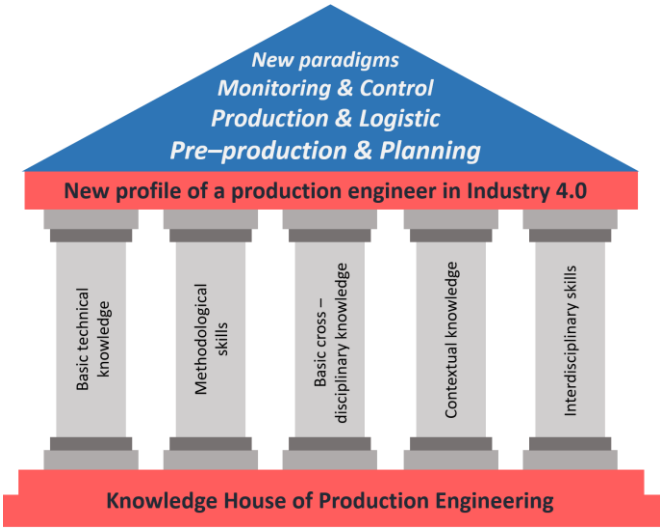


Fig. 3 *Knowledge house of production engineering in Industry 4.0*

4. Current state of art in production engineering curricula at UNS-FTS and UBL-FME

In the past, the university education system has often been slow to embrace innovation. Educational institutions are reluctant to introduce systemic changes and wait years, if not decades, to change. Innovations in the education system are difficult to spread because they disrupt established routines. This can also be explained by specific barriers that prevent change in education, which relate to the following:

- Professors are very often suspicious of brought about changes and have very little tolerance for something new and unknown,
- Lack of trust in professors when proposing innovations,
- Professors have little incentive to develop and introduce innovations in education,
- Introducing innovations often requires tremendous effort and commitment from many stakeholders,
- Lack of modern equipment and infrastructure, the acquisition of which would require large investments.

Currently, in the Republic of Serbia and Bosnia and Herzegovina, there are no national curriculum guidelines for the education of production engineers in the context of Industry 4.0. For this reason, analyzing the compliance of current production engineering curricula with the requirements of Industry 4.0 is a very complex task. In this analysis, it is important to keep in mind that the results of numerous studies show that companies are increasingly demanding soft skills, especially communication skills, over and above technical expertise. In addition to reading and writing skills, foreign language skills are also part of these communication skills and are in high demand by companies [10].

Table 2 shows when production engineering curricula were last accredited at UNS-FTS and UBL-FME. Both faculties have organized academic studies (Bachelor and Master) according to the principles of the Bologna Declaration based on the 4+1 system. The programmes consist of compulsory and elective courses.

Table 2: Latest revisions of the curricula of production engineering courses

University - Faculty	Latest revision of the curriculum of the production engineering course	Study model
UNS-FTS	2020 (there were no changes compared to the accreditation 2013)	4+1
UBL-FME	2016 (study model 3+2 replaced by study model 4+1)	4+1

The analysis of the compliance of current production engineering curricula with the requirements of Industry 4.0 was carried out by comparing the knowledge offered by these programs with the tasks that production engineers (tasks are shown at the top of Figure 3) will have to perform in the context of Industry 4.0. The results of the analysis are presented in Table 3.

Table 3: Major university disciplines that could encompass skills and competencies of Industry 4.0

The main task	Subtasks	Disciplines	UNS-FTS	UBL-FME
Pre-production & planing	Research & Development and product design	Science in the context of production engineering (mathematics, physics, mechanics, thermodynamics, fluid mechanics, materials)	+	+
		Basic cross-disciplinary knowledge (electrical engineering, mechatronics)	+/-	+
		Computer programming	-	+
		Applied programming and computer science	-	-
		Engineering graphics communications	+	+
		Fundamentals of design	+	+
		CAD techniques and rapid prototayping	+	+
		Reversible engineering	+	-
		Virtual, augmented or mixed reality (VR/AR/MR)	+	-
	Resource Planning & Sourcing	Probability and statistics	+	+

		Applied engineering statistics and time series analysis (Big Date analysis)	-	-
		Database of production processes	+	-
		Production systems	+	+
		Modelling, optimisation and simulation of production systems by artificial intelligence methods	-	-
	Staff augmentation & Management	Organization of production	+	+
		Automation in production engineering – numerical control machines and systems	+	+
Production & logistic	Machining, Production & Assembly	Manufacturing technologies (machining, metal forming, welding, etc.), machine tools, tools and fixture	+	+
		Additive manufacturing	+	-
		CAD/CAE/CAM and CIM systems	+	+
		Process planning and CAPP systems	+	+
		Modern industrial metrology	+	+
		Assembly technologies	+	+
		Digital factories	-	-
	Supply chain management	Optimization and logistics in production	+	-
	Warehousing & Transportation	Robotics	-	+
		Autonomous vehicles within warehouses	-	-
Monitoring & control	Operations, Maintenance & Continuous Improvement	Contemporary Maintenance Techniques	-	+
	Quality, Risk & Compliance	Quality control	+	+
	Health, Safety & Environment	Basics of work safety on processing machines	+	-
		Ecological technologies and systems	+	-
New paradigms	Cybersecurity	Cybersecurity in manufacturing	-	-
	Product-Service Systems	PLM systems	-	+
	Sustainability & Circular Economy	Circular manufacturing systems	-	-

5. Discussion of results

When analyzing the disciplines studied in production engineering curricula at the University of Novi Sad and the University of Banja Luka, it is clear that these disciplines most often deal with traditional production processes and technologies. The current curricula still do not fully include the skills and competences in the context of Industry 4.0, although these curricula were revised in 2020 and 2016, respectively.

The majority of disciplines in production engineering subjects focus on production processes and technologies, while very few disciplines deal with computer science, applied programming, applied engineering statistics, time series analysis (Big Data analysis), and artificial intelligence, and these disciplines are the pillars on which Industry 4.0 rests. In addition, it is necessary to include disciplines related to digital factories, cybersecurity in manufacturing, and circular manufacturing systems in both study programs. The study program of production engineering at UNS-FTS should be enriched with additional knowledge in the areas of mechatronics, robotics, autonomous vehicles within warehouses, contemporary maintenance techniques and PLM systems.

The production engineering study program at UBL-FME, on the other hand, should be additionally enriched with knowledge in the area of virtual, augmented or mixed reality, database of production processes, additive manufacturing, autonomous vehicles within warehouses, optimization and logistics in production, basics of work safety on processing machines, ecological technologies and systems.

6. Conclusion

Digitalization will bring new challenges and change the skills required for successful production engineering. The aim of this study was to investigate the impact of Industry 4.0 on the development of production engineering curricula at two universities in AP Vojvodina and the Republic of Srpska. It is evident that the curricula and study programs that currently exist in production engineering programs at UNS-FTS and UBL-FME should be redesigned to include the skills and competencies required by Industry 4.0.

7. References

1. H. Lasi, P. Fettke, H. G. Kemper, T. Feld, M. Hoffmann, Business and Information Systems Engineering, **6**, 4, pp. 239-242, (2014)
2. A. Petrillo, F. De Felice, R. Cioffi, F. Zomparelli, Digital Transformation in Smart Manufacturing, Chapter **1**, pp. 1-20, (2018)
3. D. Mourtzis, *In International Conference on the Industry 4.0 Model for Advanced Manufacturing*, pp. 194-210, (2018)
4. *Skills for Industry Curriculum, Guidelines 4.0: Future-proof education and training for manufacturing in Europe*, Executive Agency for Small and Medium-sized Enterprises, (2020)
5. B. L. Walsh, Education 4.0 — How We Will Learn in the Fourth Industrial Revolution, (2018) https://medium.com/@brianna_91610 /education-4-0-how-we-willlearn-in-the-fourth-industrial-revolution -e17206b73016
6. S. Das, D. Kleinke, D. Pistrui, *In 127th ASEE Annual Conference*, paper ID 29428, (2020)
7. E. Abele, J. Metternich, M. Tisch, G. Chryssolouris, W. Sihn, H. Elmaraghy, V. Hummel, F. Ranz, Procedia CIRP, **32**, pp. 1-6, (2015)
8. M. Sekulic, M. Milosevic, A. Aleksic, S. Borojevic, B. Sredanovic, *In 10th International Scientific Conference IRMES 2022*, pp. 91-96, (2022)
9. M. Kleindienst, M. Wolf, C. Ramsauer, V. Pammer-Schindler, *In 16th International Conference on Knowledge Technologies and Data-driven Business*, (2016)
10. G. Souza, O. Quelhas, G. Marchisotti, J. Neto, R. Anholon, C. A. Marinho, South African Journal of Industrial Engineering, **31 (4)**, pp. 136-150, (2020)

Acknowledgment

This research (paper) has been supported by the Provincial Secretariat for Higher Education and Scientific Research AP of Vojvodina through project No. 142-451-1792/2022-01/2 "The impact of the Industry 4.0 concept on the transformation of modern university engineering education in AP of Vojvodina and Republic of Srpska".

Accounting education and sustainability reporting

Eleonora.Stancheva-Todorova
Faculty of Economics and Business Administration – Sofia University "St. Kliment Ohridski", Bulgaria
e_stancheva@feb.uni-sofia.bg

Abstract: *A recent challenge towards accounting education that is expected to amplify its transformation in a span of a decade is the sustainability reporting which has already started to reshape the corporate reporting landscape. As a result of its standardisation, a recently emerged trend that currently dominates the development of the sustainability reporting, the companies are forced to enhance disclosures about their environmental and social impact. This will increase the requirements of employers in regards of the core skills and competences of the future accountants. In light of this new trend that continues to reshape the future of the accounting education along with the Fourth industrial revolution, this paper aims at analysing the impact of sustainability reporting and approaches for implementing it into the accounting curriculum.*

Keywords*: ACCOUNTING EDUCATION, SUSTAINABILITY REPORTING, IMPLEMENTATION APPROACHES*

1. Introduction

In the last decade, the accounting educators have been experiencing high pressure from employers to enhance the technological content of the accounting modules by implementing data analytics, artificial intelligence, machine learning, blockchain and other recent technology advances. Moreover, the international professional accounting and accrediting bodies have been pushing universities to restructure their programmes and update their syllabuses in response to the current transformations of the accounting profession. Industry 4.0 continues to challenge academics by imposing new demands for graduate core competences and new educational standards in the technology-rich environment. A recent challenge towards accounting education that is expected to continue its transformation in a span of a decade is sustainability reporting which has already been started to reshape the corporate reporting landscape. Companies are forced by regulators to enhance disclosures about their footprint on the environment and society which will significantly impact the core skills and competences of the future accountants considered to become the "eco-warriors" of the organisations [1].

In light of this new trend that continues to reshape the future of the accounting education along with the Fourth industrial revolution, this paper aims at analysing the impact of sustainability reporting and approaches for implementing it into the accounting curriculum.

2. Development of sustainability reporting

Sustainability reporting is relatively new in the history of company's corporate reporting. According to [2], its origin might be traced back to 1980s when the stakeholders' focus in US was shifted towards the impact of organisation activities on the environment and the disclosure of non-financial information. [3] argue that its roots could be tracked down to 1960s when the volume and variety of environmental and social information included in corporate publications began to increase. The discussion paper "The Corporate Report" is considered to be the first formal attempt for reviewing users, purposes and methods of financial reporting. The document was published in 1975 as a result of the joint efforts of several well-known professional accounting bodies in UK, including the Institute of Chartered Accountants in England and Wales (ICAEW). The report identified a new trend in the corporate reporting by manifesting the need for additional performance indicators beside company's distributable profit [4]. It is also considered to be the origin of the integrated reporting, although the first integrated report of Novozymes was published few decades later in 2002.

If we refer to the timetable suggested by [3] and further developed by [5] and [6], the initiation phase of sustainability reporting started in the early 1990s. The launch of the Global Reporting Initiative (GRI) in 1997 is considered to be one of the most notable events at that time. It was founded in Boston, USA as an international independent organisation aiming to improve sustainability reporting worldwide [7]. The first GRI guidelines were published few years later, providing the first global framework for sustainability reporting. They were updated and expanded in several versions and in 2016 the fourth version transitioned into GRI Standards. According to [8], [9] and [10], the GRI frameworks enhanced comparability of company's sustainability performance. They also improved the assurance level of sustainability reports and investors' confidence in the capital markets [11], [12].

Another notable event that speeded up the development of the sustainability reporting was the launching of the United Nations (UN) Global Compact in 2000 by Secretary-General Kofi Annan. It introduced ten principles related to human rights, labor force, environment, and anti-corruption, to be followed by companies along with the UN 17 global goals set up in the context of 2030 Agenda. At the turn of the century, the sustainability reporting became the mainstream corporate reporting. The Accounting for Sustainability project (A4S) was set up by the Prince of Wales in 2004 with the aim to support the development of practical guidance and frameworks and improve the tie between organisations' environmental and social performance and their strategy and financial performance. A4S is considered as the precursor of the integrated reporting movement, which intensified in the next years. Furthermore, in August 2010, the International Integrated Reporting Council (IIRC), previously the International Integrated Reporting Committee, was founded by the Prince of Wales's A4S, GRI and the International Federation of Accountants. Its main goal was to develop a globally accepted framework that helps companies to communicate with the stakeholders the value they create over time. The first Integrated Reporting (IR) framework was published in December 2013 to amplify the worldwide adoption of the integrated reporting which ties together in a structured and consistent way company's financial and non-financial information. The framework enhances the definition of the company's capital base by introducing new sources of capital such as intellectual, human, social and relationship, and manifests the importance of the integrated thinking, decision-making and actions of the organisations that are focused on the value creation over the short, medium, and long term.

In October 2015, the UN 2030 Agenda for Sustainable Development was published and announced the 17 Sustainable Development Goals (SDGs) and 169 targets. Two years later, the Guidance for Corporate Reporting on SDGs was launched in collaboration between GRI and UN Global Compact. It aimed at helping companies to implement SDGs reporting into their existing processes. The Taskforce for Climate-Related Financial Disclosures (TCFD) was founded in the same year by the Financial Stability Board to provide guidance on how the information on financial implications of climate-related risks and opportunities should be disclosed as the financial risks associated with the climate change were underreported at that time [13].

Despite the many undertaken initiatives and published guidance and frameworks, the lack of one single broadly accepted set of standards for non-financial reporting has been challenging companies and investors. The start of the standardisation period of sustainability reporting was marked by the establishment of the US Sustainability Accounting Standards Board (SASB), founded as a non-profit organization in 2011. It develops industry-specific sustainability disclosure standards which require the listed companies in the country to present qualitative information and industry-specific performance metrics in their corporate reports. The most important events and initiatives that labeled the standardisation of the sustainability reporting are presented in Table 1 with a break down showing whether they were initiated internationally or at the EU level.

Table 1: *Standardisation of the sustainability reporting*

2010-Present	*At the international level:* • The launch of the Sustainability Accounting Standards Board (SASB) (2011) • GRI's Sustainability Reporting Guidelines G4 transitioned into GRI Standards (2016) • The launch of the Global Sustainability Standards Board (2016) • The white paper of the World Economic Forum defining 21 core metrics (2020) • IIRC merged with SASB to form the Value Reporting Foundation (June 2021) • The establishment of the International Sustainability Standards Board of IFRS Foundation (3 November 2021) • The Climate Disclosure Standards Board (CDSB) was consolidated into the IFRS Foundation to support the work of ISSB (31 January 2022) • The ISSB's first published exposure drafts (March 2022) • Value Reporting Foundation was consolidated into the IFRS Foundation to help establish the ISSB (June 2022)
2014-Present	*At the European level:* • Directive 2014/95/EU on non-financial reporting • A proposal for a Corporate Sustainability Reporting Directive (21 April 2021) • Sustainability Reporting Technical Expert Group of EFRAG Sustainability Reporting Board (April 2022) • The first set of exposure drafts of the EU Sustainability Reporting Standards (published on 27 April 2022)

Source: based on [6].

The transition of G4 Sustainability Reporting Guidelines into GRI Standards in 2016 is another significant event that marked the period. The GRI Standards became the first globally accepted and widely used standards for sustainability reporting. A special body - the Global Sustainability Standards Board, was formed to develop and approve the GRI Standards. The latter are regularly updated and evolve to cover new topics and sector specifics. With their last update in May 2022, they were linked to UN SDGs [14].

The sustainability reporting landscape is going to change significantly as a result of the establishment of the International Sustainability Standards Board of IFRS Foundation (ISSB) on 3 November 2021. It was a response for the increasing demand of high quality, transparent, reliable, and comparable reporting by companies on climate and other ESG matters. It will push ahead the standardisation across markets by forcing the consolidation of standards and framework-setters and developing a comprehensive global baseline of investor-focused sustainability disclosure. ISSB published its first exposure drafts in March 2022 - IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Disclosure and IFRS S2 Climate-related Disclosures.

3. The sustainability disclosure standards of ISSB

It is considered that the two sustainability standards when finalised will become a comprehensive global baseline of sustainability disclosures. Many well-known organisations support the idea such as the International Organisation of Securities Commission. ISSB standards are targeted to meet the demand of the global capital markets as investors have to be informed about sustainability related risks and opportunities when assessing enterprise value. The latter incorporates a broader concept as it encompasses company's impacts and dependencies on people, the planet and the economy along with the information reported in the financial statements.

The draft IFRS S1 requires companies to disclose sustainability-related financial information about its governance, strategy, risk management and the metrics and targets that are used to measure and mitigate significant related risks and opportunities. The disclosed information has to be fairly presented and reported as part of the general-purpose financial statements. When needed, the requirements of the ISSB standards might be complemented by other standards and frameworks which are designed to meet the information needs of investors, such as the industry based SASB Standards. The companies should apply them when identifying the sustainability related risks and opportunities or refer to other companies which operate in the same industry or geographical area. Applying judgement is another alternative in the absence of relevant standards or frameworks. The draft IFRS S1 also provides guidance on how the appropriate metrics, including cross-industry and industry-based metrics should be identified. [15]

The proposed Standard requires the sustainability-related risks and opportunities to be disclosed across the company's value chain, defined as 'full range of activities, resources and relationships related to a company's business model and the external environment in which it operates' [16, p. 41]. Those activities, resources and relationships should be part of entity's operations and comprise of 'human resources, those along its supply, marketing and distribution channels such as materials and service sourcing and product and service sale and delivery; and the financing, geographical, geopolitical and regulatory environments in which the entity operates' [16, p.41].

Sustainability related disclosures are specific for each company as they might be impacted by a variety of factors such as entity's activity or the industry in which it operates, its location, the manufacturing process, by its employees and supply chain and how it relies on them.

IFRS S1 requires a disclosure of connected information which enables investors to assess the relation between different sustainability related risks and opportunities and how it is related to information in the financial statements. For instance, if the company closes a production facility because it generates high level of green house emissions, it needs to disclose an explanation about the financial implications of that decisions – how it affected its assets, the impairment losses, if any, the consequences for the employees who will lose their jobs and for the local businesses as this information impacts its reputation.

The draft IFRS S2 deals with the climate-related physical and transition risks and opportunities. Physical risks emanate from climate change and could be event-driven, for instance the severity of extreme weather events such as cyclones, floods, etc., or related to longer-term shifts in temperature or increased variability in weather patterns, for instance the rise of the sea level. The transition risks, on the other hand, are associated with the transition to a lower-carbon and its impact on the company and the most common relate to policy and legal actions, market responses, technology changes and reputational implications. A market risk is the reduced demand for a company's product that is high-carbon manufactured, an example for a technology risk will be substitutes for diesel vehicles that produces lower carbon emissions. The company should identify and explain all its climate-related risks. [17]

A summary of the draft IFRS S2 requirements related to governance, strategy, risk management, metrics and targets is provided in Table2.

Table 2: *Summary of the draft IFRS S2 requirements*

Governance
• disclose information about company's governance board or committee with oversight of climate-related risks and opportunities – the terms of reference, the management's role, the skills and competences of its members • governance disclosures should be integrated with the company's oversight of sustainability-related risks and opportunities
Strategy
• disclose information about how climate change is expected to impact company's business model, strategy and cash flow over time – in the short, medium or long term • company's plans for responding to climate-related transition risks and opportunities – how the climate-related targets will be achieved, funded and reviewed; how it will adapt or mitigate the climate-related risks, incl. indirect ones; whether carbon-offsetting is included in its plan • disclose explanation of the impact of the significant climate-related risks and opportunities on its financial position, financial performance and cash flows • company's expectation about how its financial position will change over time given its strategy to adapt or mitigate significant climate-related risks and opportunities • disclose information that will help investors to assess company's resilience to climate-related risks and opportunities, including its available finance to withstand those risks and take advantage of those opportunities • perform climate-related scenario analysis and disclose how it aligns with the recent international agreements on climate change
Risk management
• disclose information about the used processes for management climate-related risks and opportunities • explain how these processes are integrated into company's overall risk management process • disclose how it prioritises climate-related risks relative to other types of risks, including the used risk assessment tools
Metrics and targets
• disclose its absolute gross greenhouse gas emissions generated during the reporting period, measured in accordance with the *Greenhouse Gas Protocol Corporate Standard,* expressed in metric tons of CO_2 equivalent and the intensity of those emissions. • Disclose industry-based information by referring to its business model and associated activities

Source: [15], [17].

The draft IFRS S2 encompasses 77 industry classifications across 11 sectors and refers to SASB Standards for the related disclosures. Only nine of the industry-based sets of disclosure requirements do not include climate-related disclosure topics.

IFRS Sustainability Disclosure Standards might be applied with any financial reporting frameworks and standards, including the International Financial Reporting Standards. They are not mandatory, but it is expected that companies will voluntarily apply them as they represent a comprehensive global baseline of sustainability disclosures.

4. Implementing sustainability reporting into the accounting curriculum. Challenges for universities

Sustainability reporting expands the knowledge and competences required from the accounting graduates. As a response to this challenge, some universities have already started to introduce it into their accounting curriculums. The insight form academia reveals that it is a common practice to implement sustainability reporting issues into Integrated Reporting module. For example, University of Sussex included such module in its bachelor' programme Accounting and Finance [18]. The Hague university of applied science incorporated Integrated Reporting module into Finance & Control degree programme. The course is also compulsory main subject in the English-language variant – the International Financial Management & Control curriculum and in the Dutch-language variant as of 2022 [19]. University of York, on the other hand, introduced Ethics & Sustainability Reporting module since 2020-2021 academic year onward. The module syllabus encompasses a range of approaches to measuring and reporting on social and environmental performance including, but not limited to Social Accounting and Triple Bottom Line sustainability reporting [20]. The Institute for Sustainability Leadership at the University of Cambridge offers a variety of online courses on sustainability issues such as Sustainable Finance, Business Sustainability Management, Sustainable Supply Chain Management, etc. and more than 16,000 students have already completed an online sustainability course [21]. Regent's University London developed a bachelor programme in Business and Sustainability with few sustainability core subjects included in its curriculum such as Sustainability Now, Sustainable Organisations, Sustainable Operations, Sustainability in Action and Sustainable Leadership. [22]

Another alternative for accounting students is to take sustainability reporting course after graduation as part of their professional qualification. Currently, many professional education centers, consultancy firms and professional organisations offer training and certificates in sustainability reporting. For instance, Harvard Business School Online offers Sustainable Business Strategy course [23]. The Association of Chartered Certified Accountants (ACCA) provides Certificate in Sustainability for Finance [24].

Universities need relevant education resources to support the implementation process. Sustainability reporting is relatively new form of corporate reporting that is still in its early stage. Training the academic staff on sustainability reporting issues, including applicable standards and guidance, good practices and ethical considerations requires time and resources. The development of high-quality study materials is also a challenge for the accounting educators. The accounting professional organisations and the Big 4 companies might provide teaching resources – presentations, case studies, etc.

5. Conclusion

Currently universities follow two approaches for implementing sustainability reporting into their curriculums – a focused and integrated approach [25]. Sustainability reporting might be offered as a stand-alone module, or it could be implemented into the integrated reporting module. Furthermore, the development of one common single set of sustainability disclosure standards enables accounting educators to focus on one sustainability reporting framework presented by the ISSB standards instead of teaching different frameworks, guidance and standards.

6. References

1. Ryder, B. (2022) In EY's split, fortune may favour the dull, *The Economist*, published online 23 June 2022.
2. ICAEW (November 2009), Outside Insights. Beyond Accounting,https://www.icaew.com/-/media/corporate/files/technical/sustainability/assessing-the-impact-of-sustainability-reporting.ashx?la=en, (accessed 15.01.2022).
3. IMA & ACCA Joint Research (January 2016), From Share Value to Shared Value: Exploring the Role of Accountants in Developing Integrated Reporting in Practice, https://www.integratedreporting.org/resource/acca-and-ima-from-share-value-to-shared-value/ (accessed 20.01.2022).
4. ICAEW (July 1975), The Corporate Report. A White Paper, https://www.icaew.com/library/subject-gateways/corporate-reporting/the-corporate-report (accessed 05.01.2022).
5. Stancheva, E. & Ankova, A. (2017), Convergence of Financial and Management Accounting in the Context of Companies' Integrated Reporting, Proceedings from the 4th International Conference on Governance & Strategic Management "THE CIRCULAR ECONOMY-2017", BFU, Burgas, 11 - 12 May 2017.
6. Stancheva-Todorova, E. (2022) Recent and future trends in sustainability reporting, to be published in: Proceeding from the International Scientific Conference 'The Black Sea – Doors and Bridges', 10-11 June 2022, Burgas: Burgas Free University.
7. Deloitte (September 2014), Navigating the Evolving Sustainability Disclosure Landscape, http://www2.deloitte.com/content/dam/Deloitte/us/Documents/risk/us-aers-sustainability-reporting-landscape.pdf (accessed 24.01.2022).
8. Gray, R. (2010), A Re-Evaluation of Social, Environmental and Sustainability Accounting: An Exploration of an Emerging Trans-Disciplinary Field?, Sustainability Accounting, Management and Policy Journal, 1, 11-32, https://doi.org/10.1108/20408021011059205.
9. Dhaliwal, D. S., Li, O. Z., Tsang, A., & Yang, Y. G. (2011), Voluntary Nonfinancial Disclosure and the Cost of Equity Capital: The Initiation of Corporate Social Responsibility Reporting, The Accounting Review, 86, 59-100, https://doi.org/10.2308/accr.00000005.
10. Van Bommel, K. (2014), Towards a Legitimate Compromise? An Exploration of Integrated Reporting in the Netherlands, Accounting, Auditing & Accountability Journal, 27, 1157-1189, https://doi.org/10.1108/AAAJ-04-2013-1309.
11. Munshia, D., & Duttab, S. (2016), Sustainability Reporting Quality of Indian and American Manufacturing Firms: A Comparative Analysis, Serbian Journal of Management, 11, 245-260, https://doi.org/10.5937/sjm11-9593.
12. Haidar, H., Sohail, R. and Qurashi, S. (2021), Emerging Trends in Sustainability Reporting (SR): Comparative Literature Review in Developed, Developing and GCC Countries, Open Journal of Business and Management, 9, 2697-2718, https//doi: 10.4236/ojbm.2021.96149.
13. KPMG (December 2020), [The Time Has Come, https://assets.kpmg/content/dam/kpmg/my/pdf/time-has-comes.pdf (accessed 03.02.2022).
14. GRI (May 2022), Linking the SDGs and the GRI Standards, https://www.globalreporting.org/umbraco/Surface/ResourceCentre/PopupResource?id=8585 (accessed 06.06.2022).
15. IFRS Foundation (March 2022), Exposure Draft-Snapshot, https://www.ifrs.org/content/dam/ifrs/project/general-sustainability-related-disclosures/snapshot-exposure-draft-ifrs-s1-general-requirements-for-disclosure-of-sustainability-related-financial-information-and-exposure-draft-s2-general-sustainability-related-disclosures.pdf (accessed 28.07.2022).
16. ISSB (March 2022), [Draft] IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information, https://www.ifrs.org/content/dam/ifrs/project/general-sustainability-related-disclosures/exposure-draft-ifrs-s1-general-requirements-for-disclosure-of-sustainability-related-financial-information.pdf (accessed 28.07.2022).
17. ISSB (March 2022), [Draft] IFRS S2 Climate-related Disclosures, https://www.ifrs.org/content/dam/ifrs/project/climate-related-disclosures/issb-exposure-draft-2022-2-climate-related-disclosures.pdf (accessed 28.07.2022).
18. https://www.sussex.ac.uk/study/modules/undergraduate/2021/N1613-integrated-reporting (accessed 20.10.2022).
19. https://www.thehagueuniversity.com/research/centre-of-expertise/projectdetails/integrated-reporting (accessed 20.10.2022).
20. https://www.york.ac.uk/students/studying/manage/programmes/module-catalogue/module/MAN00034M/latest (accessed 15.10.2022).
21. https://cisl-onlinecourses.getsmarter.com/presentations/index/cam-sustainability/?ef_id=c:524329159340_d:c_n:g_ti:kwd-439818089015_p:_k:%2Bsustainability%20%2Bcertification_m:b_a:126434508441&gclid=EAIaIQobChMI0uKU0MOP-wIVmdOyCh0PtgrXEAAYASAAEgLKVPD_BwE&gclsrc=aw.ds#pm-faq (accessed 25.10.2022).
22. https://www.regents.ac.uk/undergraduate/business/ba-hons-business-and-sustainability?gclid=EAIaIQobChMI-Zf8o8WP-wIV3AWiAx2r-w5SEAAYAyAAEgKKxPD_BwE#academic-calendar (accessed 22.10.2022).
23. https://online.hbs.edu/courses/sustainable-business-strategy/?c1=GAW_SE_NW&source=INTL_SBS&&cr2=search__-__nw__-__international__-__sustainable_business_strategy&kw=sustainable_development_online_course_brd&cr5=523134506877&cr7=c&hsa_cam=1396947503&hsa_grp=116737571210&hsa_mt=b&hsa_src=g&hsa_ad=523134506877&hsa_acc={792-723-8641}&hsa_net=adwords&hsa_kw=sustainable%20development%20online%20course&hsa_tgt=kwd-343600985684&hsa_ver=3&gclid=EAIaIQobChMI-Zf8o8WP-wIV3AWiAx2r-w5SEAAYAiAAEgLVUvD_BwE (accessed 15.10.2022).
24. https://www.accaglobal.com/pk/en/qualifications/glance/certificate-in-sustainability-finance-certsf/information-for-employers.html (accessed 25.10.2022).
25. Dzuranin, A., Jones, J. & Olvera, R. (2018) Infusing data analytics into the accounting curriculum: A framework and insights from faculty, Journal of Accounting Education, 43, 24–39.

On the Possibility of Interpretable Rules Generation for the Classification of Malware Samples

Ján Mojžiš
Institute of Informatics, Slovak Academy of Sciences, Bratislava, Slovakia
jan.mojzis@savba.sk

Abstract: *Nowadays, sophisticated models and approaches are used in the field of Malware classification or detection. Modern trends propose the use of black-box kind of models like Deep learning or Neural networks, thus, often, the results are not human-interpretable. In this paper we focus on the well-known EMBER dataset with the focus on interpretable models like Decision trees and Decision tables. We were able to generate interpretable classification trees, which can serve in conjunction with the concept-learning or as a support for ontology creation.*

Keywords*: MALWARE CLASSIFICATION, RULE-BASED CLASSIFICATION, INTERPRETABLE RULES*

1. Introduction

Traditionally, signature-based algorithms are used in antivirus detection schemas. It is a classical detection concept where parts of the malware code (signatures) are compared with the records of malicious signatures dataset. This classical concept requires a well-prepared signatures dataset, frequently updated as new variations and modifications of malicious codes are manifested every day. No malware can be detected if its signature is absent in the dataset. Malware can be also modified by its author rendering its signature in the dataset useless. In general, we see three main disadvantages of this signature-based detection schema. The necessity of up-to-date signatures dataset (1), detection is based only on signatures present in the dataset (2), modification of malware can bypass signature-based detection (3). To properly address these issues, we can alter an old, strict signatures-based detection schema with more detection flexibility. In that, signatures importance is balanced with additional information. For instance, features about whether a malware is using mutexes, what kinds of memory operations is it using and whether it is a DLL type of binary just to name few.

In the literature, machine learning algorithms are used for malware classification (malign or benign code) with features extracted from the binary codes. A machine learning algorithm can deal with increased number of features and even the results of the malware classification can be interpretable. Interpretable results may be further used for detection process improvement. Interpretability answers why the code is determined to be malign or benign by the model. For the scope of this work, we limit our attention on the interpretable models because results – set of rules may be further used in the detection process improvement (malware detection ontology or general tasks in description logics).

Romeo et al. [1] 2018 used decision trees for interpretable results with additional focus on monotonic static features. Kilgallon et al. [2] 2017 focused on the analysis of static and dynamic features. Beside SVM or neural network (NN) models they used also (potentially) interpretable Decision Tree and K-Nearest Neighbors models. While the interpretable models have lower accuracies, in general, it is not that dramatic if accuracy drops by a few percentual points in comparison to SVM or NN. The achievement of interpretability is of much greater value here. The motivation for us is the work of Švec et al. [3] focused on the malware ontology creation with the use of EMBER [4] dataset. Before we discuss deeper into the details of our research, we provide details on the model we use in this paper.

2. Decision tree

Regarding interpretable models, for this paper, we further limit our focus on Decision Tree model. More specifically C4.5 (marked as J48 in the program Weka) designed by Quinlan [5]. Decision tree type model maintains a hierarchic structure out of input features. This hierarchic structure (tree) is composed of nodes and leaves creating paths. Path begins in the root and ends in a leaf. Starting is a feature in the root covering most of the samples, next are nodes, each intended for a particular feature and subset of samples. Path is ending with the leaves. Leaf defines the class (malware or benign) of a particular sample. For instance, in the root, there may be most important feature, like whether a given sample is a DLL or executable type of binary. If the model is binary (true or false), then this feature effectively splits the whole dataset into two parts: DLL-based and executable-based samples. Similarly other features in nodes further split these two parts to several subsets based on the sample's value (true or false) of the feature present in a particular node.

3. Experiment with the EMBER dataset

In order to evaluate C4.5 Decision Tree model as a tool for the interpretable results creation, in this paper an experiment is presented on the well-known EMBER datset [4]. EMBER is a labeled benchmark dataset for training machine learning models to statically detect malicious Windows portable executable files. The dataset includes features extracted from 1.1M binary files: 900K training samples (300K malicious, 300K benign, 300K unlabeled) and 200K test samples (100K malicious, 100K benign). Each sample in the dataset consists of a single JSON file describing various features of a Portable Executable (PE) file. More details on the EMBER datset are given in [4]. For the features used, we follow Švec et al. [3] and limit feature space only to its fraction. To select features we first ranked them with Information Gain metrics and

Table 1: *Features used for our EMBER dataset experiment sorted by Information Gain metrics score.*

Feature Name	Information Gain Score
is_dll	0.159650061
has_section_high_entropy	0.096905623
has_debug	0.072046279
has_write_execute_section	0.062346390
has_multiple_executable_sections	0.060319408
has_signature	0.044176818
sect_rsrc_writable	0.040890224
sect_pdata_has_CNT_INITIALIZED_DATA	0.040852220
sect_pdata	0.040719546
sect_pdata_readable	0.040719546
has_clr	0.038817536
has_nonstandard_section_name	0.034415923
has_nonstandard_mz	0.033341221
sect_reloc_readable	0.031287958
sect_reloc	0.031177888
sect_reloc_has_CNT_INITIALIZED_DATA	0.030850303
sect_rsrc_has_high_entropy	0.030774806
has_urls_strings	0.027751663
sect_nhgxrnnn	0.027391387
sect_nhgxrnnn_executable	0.027391387
sect_nhgxrnnn_has_CNT_INITIALIZED_DATA	0.027391387
sect_nhgxrnnn_has_high_entropy	0.027391387
sect_nhgxrnnn_has_nonstandard_name	0.027391387
sect_nhgxrnnn_readable	0.027391387
sect_nhgxrnnn_writable	0.027391387

then used first 25 in descending order. Features used are listed in Table 1 along with their values of Information Gain metrics score. We use binary representation of the features. For our experiment we use WEKA, an open-source implementation of a collection of machine learning algorithms [6].

4. Results and discussion

Fig. 1 and Fig. 2 displays partial trees for benign and malign classes respectively. Table 2 lists evaluation measurements.

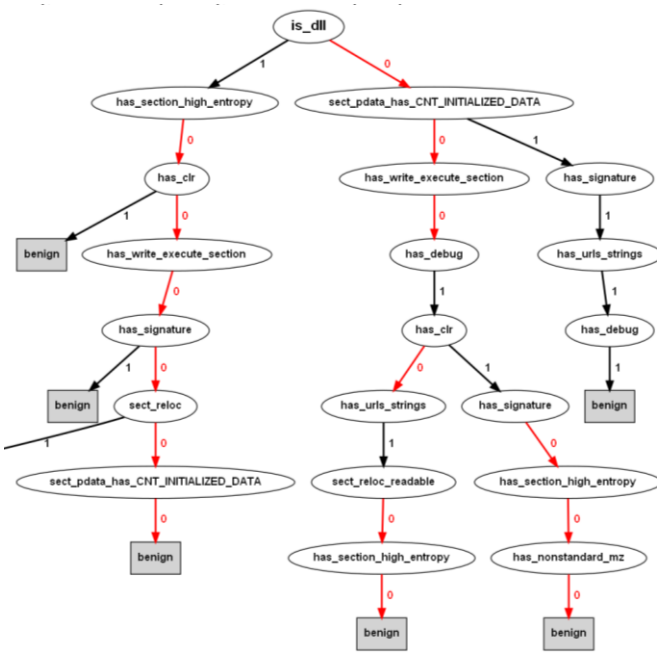


Fig. 1 *Resulting partial tree for benign class samples. Nodes are colored according to value of the feature (red for 0 and black for 1) as nodes are not placed logically (0 for left and 1 for right direction) but a layout algorithm is used to position the nodes.*

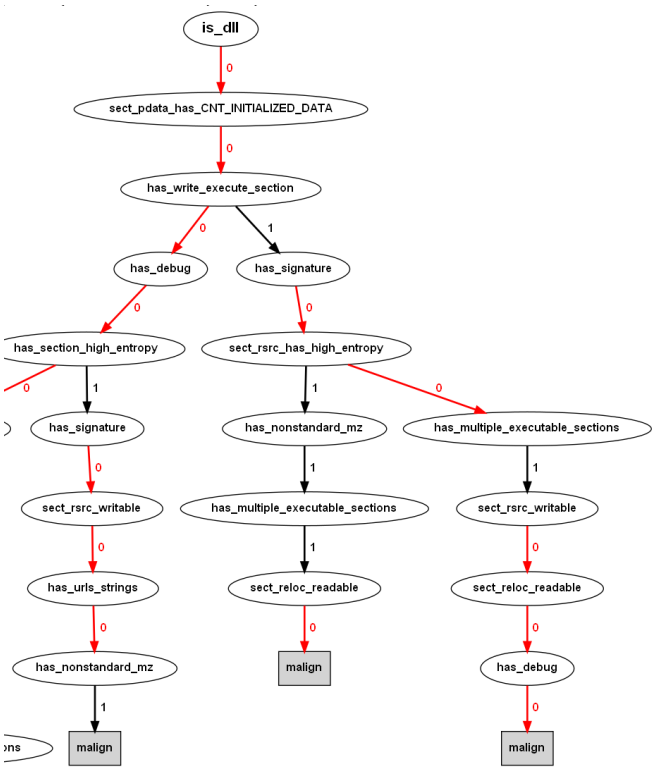


Fig. 2 *Resulting partial tree for malign class samples.*

Table 2: *Evaluation measurements of the C4.5 model used.*

	Accuracy	Precision	Recall
C4.5 Decision Tree	81.94	79,3	86,3

Based on the Information Gain (IG) scores and results displayed in Fig. 1 and Fig. 2 we can assume "is_dll" is one of the most important features in this experiment as it is placed in the root of both malign and benign trees, and it has the highest IG score. Initial decision is given with this feature and even if there are cases (not displayed in the Fig. 2) where the malign samples have "is_dll" set to 1, based on our analysis, it is just a small set of samples (15,156 in comparison to 109,843 benign samples). On the other hand, benign codes are more balanced with "is_dll" values of both values 0 and 1 (1: 109,843 and 0: 130,080). Regarding another feature "has_signature" (digital signature from a trusted signer) we can agree with Romeo et al. [1] on that it is difficult for a malware author to add a signature to his malware. This can be observed on the Fig. 1 and Fig. 2. In Fig 1. we can see that a benign code has always its feature of "has_signature" set to 1. Additionally, on the Fig. 2 for malware, we see only values of 0. This indicate that there is a lower malign samples distribution with "has_signature" set to 1 (30,923 in comparison to 80,533 benign samples). Another feature ranked high in IG metric is "has_section_high_entropy". When this feature is set to 1, a sample (either malign or benign) is using a kind of packer (UPX) to obfuscate its internal structure. Without a compatible unpacker it is merely impossible to analyze it properly. Again, a malware author could strongly benefit from such an obfuscated structure. We find that 122,931 malware samples had "has_section_high_entropy" set to 1 compared to only 40,935 benign samples.

Using these features, we can construct two example rules for benign and malign code samples respectively:

1)
   - "is_dll" = 1
   - "has_section_high_entropy" = 0
   - "has_clr" = 1

   result is benign (39,548 true positive and 336 false positive)

2)
   - "is_dll" = 0
   - "sect_pdata_has_CNT_INITIALIZED_DATA" = 0
   - "has_write_execute_section" = 1
   - "has_debug" = 0
   - "has_section_high_entropy" = 1
   - "has_signature" = 0
   - "sect_rsrc_writable" = 0
   - "has_urls_strings" = 0
   - "has_nonstandard_mz" = 1

   result is malign (24,626 true positive and 1,878 false positive)

5. Conclusions and future work

In this paper we used C4.5 Decision Tree model with EMBER dataset for malware classification. Train/test ratio was 80/20. We evaluated the model using standard metrics of precision, recall, and accuracy (Table 2) and visualized parts of the tree (Fig. 1 and Fig. 2), that was used for classification (one subtree for benign samples and one subtree for malign samples). We successfully demonstrated the extraction of two rules from these visualized trees. Rules extracted can be further used to extend or modify the existing ontology proposed in [3] for the use with description logics malware classification algorithms.

In the future we would like to improve the accuracy of this model by replacing current feature selection method of Information Gain with other method (ChiSquare [7] or two-criterial CFS [8]). Using finer selection of features could result in accuracy improvement.

6. Acknowledgment

This work was supported by a following grants VEGA no. 2/0155/19 and APVV no. APVV-19-0220.

7. References

1. Íncer Romeo, Í., Theodorides, M., Afroz, S., & Wagner, D. (2018, March). Adversarially robust malware detection using monotonic classification. In Proceedings of the Fourth ACM International Workshop on Security and Privacy Analytics (pp. 54-63).
2. Kilgallon, S., De La Rosa, L., & Cavazos, J. (2017, September). Improving the effectiveness and efficiency of dynamic malware analysis with machine learning. In 2017 Resilience Week (RWS) (pp. 30-36). IEEE.
3. Svec, P., Balogh, S., & Homola, M. (2021). Experimental Evaluation of Description Logic Concept Learning Algorithms for Static Malware Detection. In ICISSP (pp. 792-799).
4. Anderson, H. S., & Roth, P. (2018). Ember: an open dataset for training static pe malware machine learning models. arXiv preprint arXiv:1804.04637.
5. Quinlan, J. R. (2014). C4. 5: programs for machine learning. Elsevier.
6. Weka 3. http://www.cs.waikato.ac.nz/ml/weka/, accessed 2022/10/29.
7. Cochran, W. G. (1952). The $\chi 2$ test of goodness of fit. The Annals of mathematical statistics, 315-345.
8. Hall, M. A. (1998). Correlation-based feature subset selection for machine learning. Thesis submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy at the University of Waikato.

Human factor in industry 4.0 and the role of inter-generational collabotation

Monika Šestáková
School of Management, Bratislava, Slovakia
e-mail:msestakova@ vsm.sk

Abstract: The objective of the paper is to analyze pros and cons of different generations from the point of view of their readiness to satisfy the required labor skills criteria for the Industry 4.0 workforce and willingness to participate in the process of upcoming transformation. The basic conclusion is that *today´s coexistence of different generations should be transformed into an active and efficient collaboration.* In many organizations teams consisting of workers belonging to different generations will be working and in these teams older (or even middle-aged) colleagues should share their professional know-how and practical experience with younger colleagues and younger members should use their digital capabilities to achieve common objectives of the organization.
KEY WORDS: INDUSTRY 4.0, NEW REQUIREMENTS ON LABOR SKILLS, MOTIVATION AND CREATIVITY, INTER-GENERATIONAL DIFFERENCES IN EXISTING SKILLS, AGE DEPENDENT DIGITAL LITERACY

1. Introduction

The Fourth Industrial Revolution (Industry 4.0) represents a fundamental change in the way we live, work and relate to one another. It is a new chapter in human development, enabled by extraordinary technology advances. These advances are merging the physical, digital and human worlds in ways that create both huge potential benefits and promises as well as potential peril and risks. The speed, breadth and depth of this revolution is forcing us to rethink how countries develop, how organizations work and create value and even what it means to be human [18]

It is clear that the 4.th industrial revolution is about more than just technology-driven change; it will impact everyone, including leaders, policy-makers and people from all income groups and nations. Human aspects of this transformation were first mentioned in connection with the potential losing of jobs due to robotics applications. It is expected that many routine and manual activities will be automated and people from these jobs can be fired. However, new jobs will be created, many existing activities will be transformed by radically changing labor skills requirements. [12] Practical experience shows that human skills and motivation are the crucial factor for the efficiency of smart factories and all organizations in the digital era [14, 12] The new business model requires rethinking of the whole HR functions,managememt style, organization culture,etc. [8].

The crucial role of education and training to prepare the workforce of the future is generally accepted. Not only radically new skills and knowledge will be important, but also the demand for different skills and their combination will change dynamically. Ability and willingness to learn will actually be a permanent requirement in almost all professions and is inevitable for adjustment to new dynamics of changes in environment [16].

The role of human factor in Industry 4.0 can be approached from different perspectives: regional aspects, professional and industry specificities, new demands on educational system, etc In our paper we´ll deal with the inter-generational aspects of this wide problem area. In the center of our analysis will be the question *what role can different generations play in implementing or even accepting the transformation to the Industry 4.0 economy and society*.

2. Why inter-generational aspects are important

Problems of intergenerational relations are not a new phenomenon. However, a significant increase in the share of seniors in the population of developed countries today, intensifies an interest in these issues.

New technology connected with the Industry 4.0 raises radically new dimensions of the inter-generational cooperation problems. Firstly, it is clear that digital literacy and high level of digital skills, important for Industry 4.0, are unequally distributed among different generations. On the other hand, practical experience, tacit knowledge based on lessons from previous development of organizations, industries, etc. are more embodied in workers in their 40-ies or 50-s and sometimes even in seniors, These people can represent an important element of an intellectual capital of companies, mainly established firms. Also such skills required for Industry 4.0 workforce, as emotional intelligence, empathy, communication ability and experience with leading teams, are differently dispersed in the population .Of course, these features are strongly dependent on the type of a personality, but can be also supported by education system. However, the impact of an environment, in which a person has grown, is also important.

Life-long learning cannot be just a task of educational institutions. Companies should play an important role as well. Life-long learning does not mean just participation in training courses organized by employers, but to a significant degree it is based on learning by practical experience in teams or other communities. These teams include persons of different age, even belonging to different generations. For managers and companies, it is important to create such conditions that members of the team will effectively cooperate to achieve planned objectives. Transfer of knowledge (both explicit, but also tacit) between team members is very important and its role will even increase on the path to Industry 4.0.

3. How are different generations prepared and willing to participate in forming the Industry 4.0 society

New requirements on labor skills, loss of some routine jobs and the transformation of existing jobs, are differently accepted by different generations and also by different professional groups within the same generations, This is relevant not only for manual workers, but also some graduates of universities that are regarded as knowledge workers today, can become redundant due to automation. Much more higher flexibility and willingness to learn will be important in many professions. Flexibility can be a permanent feature of some individuals, it need not depend on their age. However it can be also learnt (but sometimes even reduced) by practical experience. Elderly people are mostly regarded as less flexible than the young generation. although there can be exceptions

It is well-known and statistically proven for developed countries, that digital capabilities of the population are decreasing with the age [17]. However, digital capabilities can't be the only criterion to evaluate the readiness of different generations to participate in forming Industry 4.0.

Let's start our excursion into generational aspects of the problem „How ready is the workforce for Industry 4.0" by analyzing strengths and weaknesses of the youngest generation (millenials and Generation Z), which is usually regarded as the basic supporter and human driver of Industry 4.0. Our basic source of data will be The

Deloitte Global Millenial Survey 2019 [1, 2]. The 2019 report is based on the views of 13,416 millennials questioned across 42 countries and territories. Millennials included in the study were born between January 1983 and December 1994. The report also includes responses from 3,009 Gen Z respondents in 10 countries. Gen Z respondents were born between January 1995 and December 2002. The Survey was oriented on millennials' (millennials are sometimes called GenerationY) perception of the current economic development, business motivation and their relationship to technology, especially the advent of Industry 4.0. All the respondents from the millennial cohort were working. Most of the respondents from Generation Z were still studying; some of them were simultaneously employed.

The views of respondents are rather pessimistic, and the Survey called them "a disrupted generation". According to the Survey, young participants are increasingly pessimistic and mistrustful of both their careers and the world around them. Respondents expressed a strong lack of faith in traditional societal institutions, business motivation and macroeconomic perspectives. The top priorities of the respondents were: travel and seeing the world (57 %), high salary (52%), buying a home of their own (49%).

For our paper, the most important is the attitude of millennials to the advent of Industry 4.0 and its impact. Forty-nine percent of millennials believe new technologies will augment their jobs; 25 percent expect Industry 4.0 to have no impact, and only 15 percent fear it will replace all or a part of their job responsibilities. Only about one in five respondents believe they have all the skills and knowledge they'll need for a world being shaped by Industry 4.0, and 70 percent say they may only have some or few of the skills required and will need to evolve their own capabilities to increase their value.

A serious problem for companies can be a high fluctuation rate of young people. 49 percent of respondents would, if they had a choice, quit their current jobs in the next two years. If companies invest in the training of this youngest part of their human capital, this will lead to a loss. Although labor mobility is regarded as one of the requirements of the new era, there must be some limits to the drain of talent. The basic reason of this fluctuation is dissatisfaction with the pay

According to the Deloitte Survey, millenials and Generation Z make up more than half of the world's population and, together, account for most of the global workforce. They can be – and should be – the crucial part of the workforce for Industry 4.0. They were educated for a digital society and wish to use and improve their digital capabilities to achieve their personal satisfaction but also some broader social objectives.

However, if we communicate and work with these young people, we can realize that they are very good in IT, are able to construct up-to-date mathematical models, etc., however they do not understand enough, what is behind these models, what simplifying assumptions are included in the model and what is the actual relation between virtual reality and actual economic, social etc. situation .To become more realistic and useful for actual problem solving, they have to systematically cooperate with more experienced colleagues. These colleagues can be sometimes even formally their mentors, but need not be. The knowledge transfer can be also spontaneous, informal in working communities.

What generation can play this supportive or even mentoring role? Another generation (passing from the youngest workers to higher age groups) is the Generation X. This cohort includes people born between late 1960s and the first half of 1980s. Due to a lower birth-rate at that time, this demographic group is not large (in comparison with millennials) in many countries. As an opposition to their mothers' workholism, they prefer balance between work and personal (family) life; work should be interesting and creative for them and independence is among their most important values. Members of this generation have some common features with millenials: independence, need of creativity, being skeptical of authority. The basic difference is their longer work (and practical) experience.

Over 60 percent of the Generation X in developed countries have university education. They are technologically adept. They are comfortable with smartphones, e-mail, laptops, tablets, and other technology used in the current workplace. Technology is inextricably woven into their lives [7]. They are flexible, adapt to change, friendly and tolerant of alternative lifestyles. After some retraining in the up-to-date technology, they can be valuable members of the Industry 4.0 workforce.

However there can be some limitations. Due to institutional and even political environment in many countries (Slovakia included) this generation did not occupy leading positions in organizations, their experience with leading teams and organizations is not sufficient, they used to be more passive workers, respecting regulations, than active independent decision makers.

Next generation is the baby boomers – people born after the war, between 1946 and mid1960s. It was the largest generational cohort in the USA up to 2015, and it still is an economically and politically influential generation. Many of them are even today at the top management positions. Most of them entered the workforce in the period when computers were in their rudimentary stage. Those baby boomers that were using IT in their professional careers have basic IT capabilities. However, today most baby boomers are approaching the retirement age or are already retired and represent (in the USA and some other developed countries) a relatively wealthy group of the „silver generation" – they form an important component of a demand for new products and services .

The influence of this generation on the economy and markets is sometimes called „baby boomer effect" [10]. This term was originally used in the realm of technology and referred to the importance of simplifying the interfaces of consumer electronics to encourage the wealthy baby boomer generation to upgrade. Although today the term is used in a broader sense, problem of simplifying the consumer-new products interaction can be topical for the new, Industry 4.0 era.

The generation of "veterans" (people born before the war or during the war) is usually not mentioned in connection with the digital society and forming Industry 4.0, although with the ageing population, the share of people in 55+ in the total population, and even in employment, is growing. The share of people aged 55 years or more in the total number of persons employed in the EU-27 increased from 12 % to 20 % between 2004 and 2019.[6]. In V-4 countries in 2016, the share of people in the age group 55-64 years that were working, was 41.6 percent, with the highest number in the Czech Republic (almost 90 percent). In Slovakia, this share was a little lower than 50%, but most of these workers were employed full time. Older seniors, in the age 65+ have a much lower employment rate and usually-are working at a part-time basis In 2019, 48 % of all working men aged 65 years or more in the EU-27 were employed on a part-time basis compared with 60 % of women aged 65 years or more [6, 12].

Veterans that are still working are usually in jobs where digital capabilities are not required. Many of them have access to the internet but they do not use it in their work. However, in this age group, we can also find specialists that are actually knowledge workers (mainly researchers and university teachers) and that have

been forced to acquire digital capability. Due to their tacit knowledge and experience, this part of the older generation can be valuable in educating the future workforce.

In connection with the option to more include seniors in the employment, often the role of *home office type of work* is mentioned. Under pandemic and lockdowns, the use of home office as a type of work has been widely used in many countries. This was independent on the age.

The long-term impact of widely using the home office work is still not sufficiently evaluated. Many problems are open. They include not only the impact on productivity, meeting company objectives, difficulties to apply a teamwork,etc.but also many problems from the worker´s point of view: a need of more intensive contacts with colleagues, a barrier to professional growth, another type of a disbalance between work and personal life, etc.

4.Human factor are not only employees

The human factor includes not only workers or potential employees, but it also represents all the citizens, including children, retired persons and other individuals that are not working for various reasons. All of them are tax payers (at least of indirect taxes); they have to communicate with government authorities; they will be included in the e-health system, and, mainly, all of them will be final consumers in an ever more digitalized society. In the era of Industry 4.0, some digital literacy will be necessary for all the people.

The digital divide, which exists not only between countries but also between different groups within the same country, is usually treated as the differing amount of information between those who have access to the Internet (specially broadband access) and those who do not have the access [13].

Let´s look at some data from a survey on access to the internet and use of it in Slovakia, during recent years [11]. Respondents of the survey were 2906 Slovak citizens older than 18 years. 60% of them were women, and 40% were men. The respondents were from various regions and age groups. 68% of the respondents had high school education, and 31% had university education. Digital capabilities were self-assessed by the respondents, at the scale ranged from one (I am able to do very well) to five (I am not able at all).

There were 3 basic groups of criteria for the level of digital literacy: hardware (work with computers, mobiles, computer peripherals, access to the internet), software (work with various operating systems) and the way of using the internet (search for information, e-mail, chat, social networks, calling by internet, e-commerce, internet banking, communication with government institutions, etc.). In the 1st group of indicators (hardware), assessment of men is higher than that of women. About 10% of the whole sample are „not able at all“ to work with computers, and a similar share has no access to the internet. As can be expected, digital capabilities are increasing with the level of education and declining with the increasing age. In the age group 65+ there was the lowest value for almost all the indicators of digital capabilities. The lowest level of an individual indicator has been achieved for „the work with databases“, which is very important for the work skills in Industry 4.0. Just 10% of respondents said they were able to do it very well.

From the mentioned research and also from "a common sense" point of view it is clear that a radical improvement in digital literacy of the population is badly needed .

5.Conclusion

Forming Industry 4.0 is impossible without preparing the human factor for its creation. Human skills, motivation, creativity, flexibility, critical thinking and ability to make independent decisions are very important. Some of these features can be purposefully formed by education system (both formal and life time education, based also on practical experience).Other features are dependent on a type of a personality and can be to a certain degree formed by practical experience and transfer of tacit knowledge in working communities.

On the path to Industry 4.0, companies will hire talent from outside (graduates from universities, perspective workers with some practice in other companies or organizations) and retrain existing workforce to meet new requirements. In this process , often teams or working communities can be formed, consisting of workers of different age and belonging to different generations.

In our opinion, a precondition for an efficient working of such teams is an atmosphere of trust and respecting specific preferences and values of different age groups. Moreover, people of different age must be motivated to cooperate and the collaboration should be mutually advantageous. Young people can feel that the advice of older colleagues is useful for them and older members of the team can not only acquire higher digital skills in collaborating with young colleagues (so called reverse mentoring), but have the opportunity to better understand the actual preferences and life style of the young generation. However, it is important, that neither form of mentoring will be misused and lead to a manipulation.

Literature

[1]*Deloitte (2019a) Digital Transformation Scoreboard 2018 Deloitte Insights 2019*

[2]Deloitte (2019b) Global Millenial Survey 2019

[3]*Deloitte (2020 a) 2020 Deloitte global human capital trends. Deloitte Insights 2020*

[4] EUROSTAT (2022) Ageing Europe - statistics on working and moving into retirement

[5] Fonseca,L.M.(2018) Industry 4.0 and the digital society: concepts, dimensions and envisioned benefits. *Proceedings of the12th International Conference on Business Eccellence*

[6] Gayle, L. (2019) How Generation Z is transforming the workplace, Financial Executives International, August 22, 2019;

[7]Grabisch, B.C. (2020) Disrupt Yourself, Before Someone Disrupts You. Available at https://ili.digital/challenging-corporate/beatrice-guillaume-grabisch-digital-transformation-is-a-mutual-task/

[8] Guien, I. – Asaikar, E. (2018) What is the future of human beings in the new industrial revolution. *BRIDG Insight, 27.1.2018*

[9]Hayes A. Baby boomer factor (2022) available at boomer Effect (Baby Boomer Factor) Definition (investopedia.com)

[10]Kokles et.al. (2017) Research of Digital Literacy of Population in the Slovak Republic. In:*Journal of Technology and Information Education.*2017 N.1

[11]Kostrova, J.- Grmanova,E (2018) OLDER PEOPLE IN THE LABOR MARKET AND THEIR EMPLOYMENT IN SELECTED COUNTRIES OF THE EUROPEAN UNION. In *Socialno-ekonomicka revue 2018, N.*

[12] Mckinsey &Comp.(2020) Reengineering manufacturing operations after CPVID 19.

[13]OECD (2018) Which skills for the digital era? OECD Science, Technology and Industry Working paper 2(18/09

[14]PWC (2020 a) Digital Transformation Survey 2020

[15]PWC (2020 b) 2020 Global digital IQ. Available at www.pwc.com.>consulting>digital.iq.html

[16] Veingerl. Čič, Ž – Sarotar Žižek S.(2015) Intergenerational Cooperation at the Workplace from the Management Perspective. *Research Gate* September 2017

[17]Velšic (/2020) Digitálna gramotnosť na Slovensku 2020. Inštitút pre verejné otázky and Accenture, Bratislava 2020

[18]World Economic Forum (2016) *The 10 skills you need to thrive in the Fourth Industrial Revolution.* WEF, Davos, 2016

Bratislava, Slovakia

Classification of Green Energies and Possibilities of their Effective Use

Raul Turmanidze[1], Giorgi Popkhadze[2]
Georgian Technical University (GTU), Faculty of Transportation and Mechanical Engineering, 0171 Tbilisi – Georgia[1,2]
inform@gtu.ge[1], popxadzegiorgi@gmail.com[2]

Abstract: *Wind, water, earth and fire, according to ancient philosophy, are the basic elements of the entire cosmos, with the help of which the existence of all things on planet earth is realized. Three (wind, water and earth) of these four basic elements represent renewable energy sources (RES), and in that sense also sources of green energy (GE). While the world, especially in the most developed countries of the world, has advanced far in the application of various forms of green energy, in Georgia this field is in its infancy and it cannot be predicted when the first major positive developments in this field will be made. The paper provides a basic division of sources (forms) of energy, taking into account the possibility of depletion over time, as well as examples of efficient application of hybrid green energy systems, for converting energy, primarily wind and sun, into electrical energy. Thus, the development and application of hybrid green energy systems, from a scientific and industrial point of view, will be one of the main goals in the future.*

KEYWORDS: *ENERGY, ENERGY POLICY, GREEN ENERGY (GE), SUSTAINABLE ENERGY (SE), CLEAN ENERGY (CE), RENEWABLE ENERGY (RE), RENEWABLE ENERGY SOURCES (RES).*

1. Introduction

Energy represents the ability of a body or system to do some work. There are many forms of energy, such as: Kinetic energy, Potential energy, Thermal energy (heat), Internal energy, Electrical energy, Chemical energy, Elastic potential energy and others.

One of the most commonly used forms of energy is electricity, which is a basic part of nature. It is produced by the effect of the electromagnetic field on the electric charge. It represents the so-called a secondary (or transformed) form of energy as opposed to the primary ones that occur in nature. The global tendency is for electricity production to increasingly shift to renewable energy sources (RES) for environmental reasons.

The consumption of energy in the world, from year to year, is growing, and therefore the need for its production is also increasing. The vast majority of that energy is from non-renewable sources (currently more than 80%), which is already causing undesirable consequences for the environment. One of the solutions, in accordance with the principles of sustainable development, lies in reducing the share of fossil fuels in the total production and consumption of energy. So, the share of renewable energy sources (RES) should be significantly increased in the future, because there are fewer and fewer non-renewable energy sources and their reserves are running out, and also their harmful influence has become more pronounced in the last few years. The sun, without which there is no life on our planet, gives the Earth several thousand times more energy than humanity manages to consume at the current stage of development. Everything speaks in favor of the fact that renewable energy sources (RES) can and must begin to be used better.

Currently, of the annual energy consumption, at the world level, appr. 50% spend on industry, appr. 25% is used for transport, and the remaining 25% is consumed by households and the commercial sector. Out of the total consumed of all types of energy, 40% is mostly used for the production of electricity, of which app. 60% is spent in households and the commercial sector. China and India have the highest growth in consumption of all types of energy, at the world level, and of the developed countries, the highest growth in energy consumption is recorded in the USA, while the EU records a decrease in energy consumption from appr. 2%.

If this pace of growth in energy production and consumption continues and if the predictions of scientists in this field come true, in fifty years, it is predicted that the total energy consumption will double compared to the current period. With the doubling of energy production and consumption, the consequences for the environment will be unfathomable.

The state and perspectives of the development and application of different types of green energy in different countries of the world are presented in papers [3-4, 17-19, 25-27, 29-30, 34, 38].

All these facts show that the best solution from this situation is in the increasing use of renewable energy sources (RES) and green energy (GE), which is the goal of this paper through the examples of effective application of hybrid green energy systems.

2. Classification of Natural Energy Sources

Considering the time possibility of exhaustion, natural or. primary sources (forms) of energy can be divided into (Fig. 1) [8, 11, 22, 24-25, 28, 37]:

1. Non-renewable energy sources (NRES):
   - Fossil fuels (coal, oil, natural gas, oil shale);
   - Nuclear fuels;
2. renewable energy sources (RES):
   - Water power (energy of water currents, sea currents and waves, tides);
   - Biomass and biogas, including wood and waste;
   - Solar radiation energy;
   - Wind energy;
   - Earth's internal heat (geothermal energy);
   - Tidal energy;
   - Wave energy

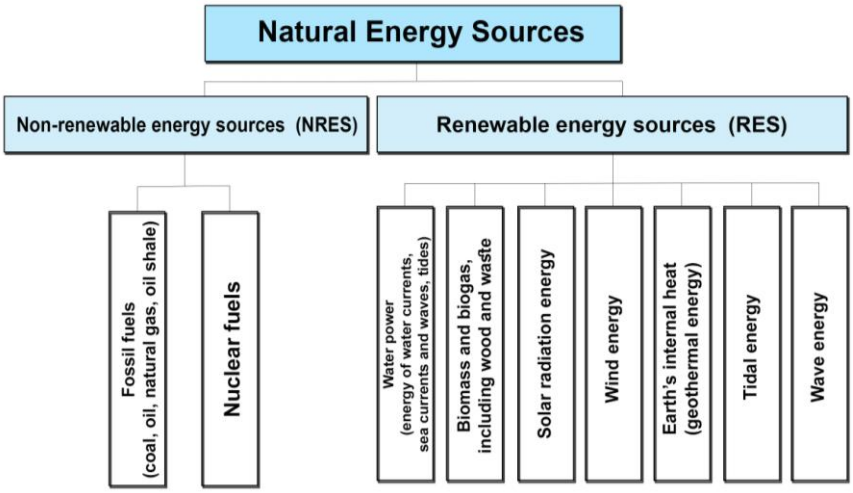


Fig. 1. *Division of natural or of primary sources (forms) of energy, considering the time possibility of depletion*

Renewable energy (RE) is that form of energy that is renewable (naturally replenished) and produced from sources that are constantly renewed, meaning that this form of energy is created from natural sources (Sun, wind, rain, waves, geothermal heat and similarly).

There are different types and categories of renewable energy sources (RES) (Fig. 1). According to the time of creation, renewable energy sources (RES) are divided into two main categories:

- traditional renewable energy sources such as biomass and energy from large hydroelectric plants and
- ”new renewable energy sources” such as solar energy, wind energy, geothermal energy and the like.

In addition to renewable energy (RE), the following terms are often used in the literature: green energy (GE), sustainable energy (SE) and clean energy (CE). The question arises whether there is a difference between: GE, SE, CE and RE energy and what is the difference.

Although the resource of these energies can be simultaneously all these forms of energy at once, it can also be e.g. renewable but not green or clean (as is the case with some forms of biomass energy). For example, energy production that burns organic material from sustainable forests is a type of renewable energy (RE), but it is not green (GE), because of the CO_2 produced by the burning process itself. Or energy sources that use mining or drilling operations that can be harmful to the environmental ecosystem are not green. Also, green energy is energy derived from natural sources, while clean energy is energy gained from sources that do release air pollutants [8, 11, 22, 24-25, 28, 37].

Green energy (GE) or sustainable energy (SE) is any type of energy that is generated from natural resources (such as: sun, wind or water), and the effect of its use is to have as little harmful impact on the environment as possible. Wherein there is a dilemma whether a hydropower dam that can divert water flows and negatively affect the local environment should really be called green [1, 5, 8, 12-16, 23, 37, 40].

The most commonly used green energy sources (GES) are: wind energy, solar energy, hydroelectric energy (including tidal energy, which uses ocean energy from the tides in the sea), geothermal energy, biomass energy and biofuels. Application of GES is expected in modern intelligent, sustainable and green manufacturing systems and digitized and smart factories [6].

The development and use of renewable and green energy, especially from the Sun, wind, water and biomass, is important for the following reasons:

- these energy sources have a very important role in reducing the emission of carbon dioxide (CO_2) into the atmosphere;
- increasing the share of renewable energy sources increases the energy sustainability of a country's system, at the same time helps to improve the security of energy supply and thus reduces dependence on the import of energy raw materials and electricity;
- in due time, renewable energy sources are expected to become economically competitive with conventional energy sources.

Economic competitiveness is already demonstrated by several technologies of renewable and green energy, especially solar energy, wind energy, small hydropower plants, energy from biomass. The main problem for the installation of new plants is their initial price, because it raises the price of the obtained energy in the first years even to the level of complete unprofitability compared to other commercially available energy sources. It should be emphasized that a large share in the production of energy from renewable sources is the ecological awareness of the population as well as the political will to invest in plants for the production of ”green” energy.

3. Examples of Effective Use of Green Energies

Through examples of effective use of green energies, solar energy will be shown, which can be produced on a small scale in people's homes or, alternatively, can be produced on a larger, industrial scale.

Solar energy (SE) is produced from the sun using photovoltaic (PV) cells that capture sunlight and directly convert it into electricity, using the PV effect without emissions, noise or vibration. PV effect depends on interaction of photons, with energy equal to, or more than, the band-gap of PV materials. Some of the losses due to the band-gap limitations are avoided by cascading semiconductors of different band-gaps [7, 10, 23]. Solar energy is also used to heat buildings and hot water, as well as for cooking and lighting. Solar energy has now become affordable enough to be used for domestic purposes, including garden lighting, although it is also used on a larger scale to power entire neighborhoods [23, 34].

Solar photovoltaic (PV) cells were invented at Bell Labs (Bell Telephone Laboratories Inc.) from Holmdel (New Jersey – USA) in 1954 and they have been used in space satellites for electricity generation since the late 1950s [11, 35].

The cost of producing electricity from sunlight is extremely high, despite the fact that sunlight is free, although prices are starting to fall. The main reason is that solar energy has a low energy density, so photovoltaic modules require a large area to produce a small amount of energy.

Main of Grid connected photovoltaic system is shown in Fig. 2, where is the primary component in grid connected PV systems is the inverter, it converts DC power produced by PV array into AC power consistent with the voltage and power quality requirement of the utility gird [23].

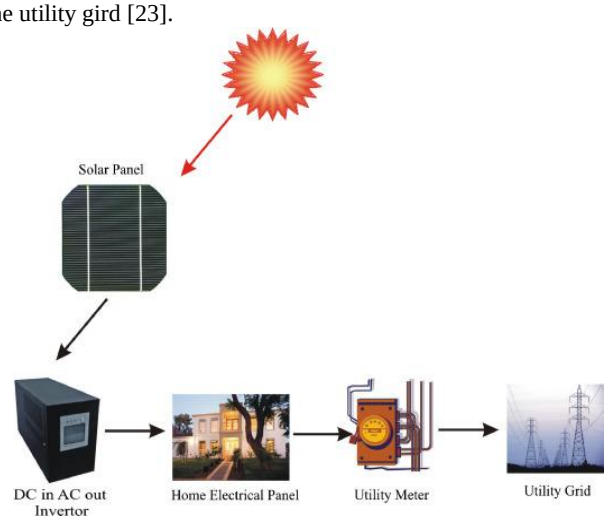


Fig. 2. *Grid connected photovoltaic system [23]*

In the following, several examples of the application of solar panels and solar PV (photovoltaic) plant in different areas of the world will be presented.

On Fig. 3 shows them solar panels installed at the Electronic faculty of the University of Niš (Serbia) for education back in 2011 and serves exclusively educational and demonstration purposes [32]. The software SUNNY DESIGN of the company SMA GmbH from Kasel (Germany) was used for the calculation of energy consumption [31].

On Fig. 4 shows them Solar tower power plants PS10 and PS20 near Seville, in Andaluzia (Spain). Heliostat field of this plant is composed of 1255 heliostats, each surface of 120 m^2. The tower is 165 m high. On the top of the tower there is a steam turbine that starts generator for the production of electrical energy. Construction of the CSP (Concentrating Solar Power) plant PS20 was begun in 2006 and it was installed in 2009. When compared to PS10, PS20 plant has bigger efficiency, better monitoring system and better thermal energy storage [20, 26].

Fig. 3: *Solar panels installed at the Eectronic faculty of the University of Niš (Serbia) [32]*

Fig. 4: *Solar tower power plants PS10 and PS20 near Seville, in Andaluzia (Spain) [20, 26]*

Solar PV energy offers the best solution for remote agriculture and there are numerous applications of solar panel technologies in agricultural farm due to innovations in agricultural technology [2]. Development and application of solar panels and solar energy technologies in agricultural sectors (agricultural systems, agriculture farming, sustainable agriculture farming, big farming, small scale farming and etc.) is shown in the papers [2, 9, 21, 25, 35-36, 39].

On Fig. 5 shows them example use of solar energy in agriculture [35].

Fig. 5: *Use of solar energy in agriculture [35]*

On Fig. 6 shown them solar photovoltaic panels providing green energy for agricultural growth [35].

Fig. 6: *Solar photovoltaic panels providing green energy for agricultural growth [35]*

On Fig. 7 shown them the space, shelter or breeding for livestock and greenhouse heating [2].

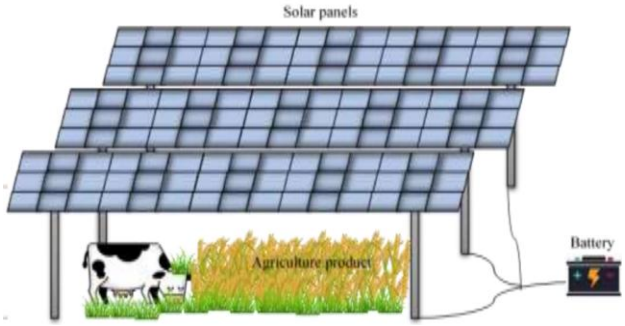


Fig. 7: *Solar panel technology system operation for both agriculture and livestock [2]*

Tractors, the most important and central technology and machine on every farm, usually use diesel oil as their energy source. Solar machines and tractors use solar energy converted into electricity. One way of using solar energy in the form of electrical energy is by using solar panels fixed on machinery or tractors (Fig. 8) [36].

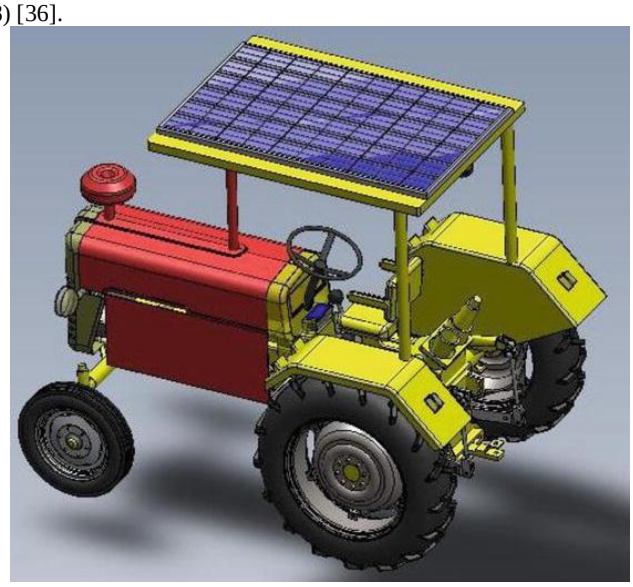


Fig. 8: *Schematic diagram of solar powered tractor [36]*

On Fig. 9 shows the Nellis Solar Photovoltaic Power Plant with power 14.2 MW located in 2007 within Nellis Air Force Base (NAFB) in Clark County, northeast of Las Vegas (Nevada – USA), as largest solar plant in this region. It covers an area of 140 hectares and consists of 72.000 solar modules that follow the movement of the sun during the day (trackers). It is estimated to produce 32 GWh per year of electricity annually and supplied more than 25% of the power used at the base and reduce CO_2 emissions by 24.000 tons per year.

Fig. 9: *Nellis Solar Photovoltaic Power Plant with power 14.2 MW (USA) [20, 25]*

On Fig. 10 shows the Waldpolonez Solar Park which is the world's largest thin-film photovoltaic (PV) power system, is built in on military air base to the east of Leipzig (Germany), with a nominal power of 40 MW. It produces 40 GWh of electricity annually. It covers an area of 2 km^2 and consists of 550.000 solar modules made of amorphous silicon and CdTe which supplies 40 GWh of electricity per year. The investment cost for the Waldpolenz solar park amounts to some 130 million Euro.

Fig. 10: *Waldpolonez Solar Park built in on military air base to the east of Leipzig (Germany) [25, 33]*

On Fig. 11 shown them the Andasol (**Anda**lusia and **Sol**) solar power station, located near Guadix in Andalusia (Spain), uses a molten salt thermal energy storage to generate electricity, even when the sun isn't shining. The Andasol is Europe's first commercial plant to use parabolic troughs with 150-megawatt (MW) power. The Andasol plant uses tanks of molten salt as thermal energy storage to continue generating electricity, irrespective of whether the sun is shining or not.

Fig. 11: *Andasol (**Anda**lusia and **Sol**) solar power station, located near Guadix in Andalusia (Spain) [20]*

On Fig. 12 shows the Serpa solar power plant (also known as Hércules solar power plant), with a capacity of 11 MW, installed in 2007 in Serpa, in Portugal's Alentejo agricultural region, 200 kilometers southeast of Lisbon. This power plant consists of 52.300 solar trackers that produce 20 GWh of electricity per year, which is enough to supply electricity to 8.000 households and reduce CO_2 emissions by 30.000 tons per year. Construction Serpa solar power plant cost of 58 million euro.

Fig. 12: *Serpa solar power plant (also known as Hércules solar power plant) (Portugal) [20, 25]*

4. Conclusion

Sources of renewable (RE) and green energy (GE) will not disappear because they are naturally replenished, unlike fossil fuels such as coal, oil or gas.

Renewable energy sources (RES) and green energy (GE) are predicted to become economically competitive with conventional energy sources in due course.

The use of renewable and green energy has a very important role in reducing the emission of carbon dioxide (CO_2) into the atmosphere.

Increasing the share of renewable and green energy increases the energy sustainability of a country's system.

References

[1] Abrell, J.; Rausch, S. & Streitberger, C.: The economic and climate value of flexibility in green energy markets. *Environmental and Resource Economics*, Vol. 83, Issue 2 (October 2022), pp. 289–312. ISSN 0924-6460. doi: 10.1007/s10640-021-00605-6.

[2] Aroonsrimorakot, S., Laiphrakpam, M., Paisantanakij, W.: Solar panel energy technology for sustainable agriculture farming: A review. *International Journal of Agricultural Technology*, Vol. 16, Issue 3 (May 2020), pp. 553–562. eISSN 2630-0192.

[3] Balat, M.: The use of renewable energy sources for energy in Turkey and potential trends. *Energy Exploration & Exploitation*, Vol. 22, Issue 4 (August 2004), pp. 241–257. ISSN 0144-5987. doi: 10.1260/0144598042886317.

[4] Bogachkova, L.Yu.; Guryanova, L.S., Usacheva, N.Yu., Usacheva, I.V.: Conditions and trends of green energy development in the largest economies of the post-soviet space. *Lecture Notes in Networks and Systems (LNNS)*, Vol. 155 (2021), pp. 152–163. ISSN 2367-3370 and ISBN 978-3-030-59125-0. doi: 10.1007/978-3-030-59126-7_18.

[5] Conroy, G.: Data are key to proving green-energy benefits. *Nature*, Vol. 609, Issue 7926 (September 2022), pp. S2–S4. ISSN 0028-0836. doi: 10.1038/d41586-022-02831-4.

[6] Dašić, P.: *Scientific and technological trends: Selected scientific-professional papers* (in Serbian). Vrnjačka Banja: SaTCIP Publesher Ltd., 2020. – 305 str. ISBN 978-86-6075-072-5.

[7] Fadaeenejad, M.; Radzi, M.A.M.; Fadaeenejad, M.; Zarif, M. & Gandomi, Z.: Optimization and comparison analysis for application of PV panels in three villages. *Energy Science & Engineering*, Vol. 3, Issue 2 (March 2015), pp. 145–152. ISSN2050-0505. doi: 10.1002/ese3.52.

[8] Filippov, S.; Mikova, N. & Sokolova, A.: Green energy prospects: Trends and challenges. *International Journal of Social Ecology and Sustainable Development*, Vol. 6, Issue 3 (July 2015), pp. 1–20. ISSN 1947-8402. doi: 10.4018/IJSESD.2015070101.

[9] Gorjian, S.; Calise, F.; Kant, K.; Ahamed, M.S.; Copertaro, B.; Najafi, G.; Zhang, X.-X.; Aghaei, M. & Shamshiri, R.R.: A review on opportunities for implementation of solar energy technologies in agricultural greenhouses. *Journal of Cleaner Production*, Vol. 285 (February 2021), Article no. 124807. ISSN 0959-6526. doi: 10.1016/j.jclepro.2020.124807.

[10] Goswami, D.Y.; Vijayaraghavan, S.; Lu, S. & Tamm, G.: New and emerging developments in solar energy. *Solar Energy*, Vol. 76,

Issue 1-3 (January-March 2004), pp. 33–43. ISSN 0038-092X. doi: 10.1016/S0038-092X(03)00103-8.

[11] Hoogwijk, M.M.: *On the global and regional potential of renewable energy sources*. Ph.D. Thesis. Utrecht (Nederlands): Utrecht University, Faculty of Chemistry, 2004. – 256 pp. ISBN 978-90-393-3640-3.

[12] Huan, Y.; Sun, Z.-J.; Ali, M.; Yan, R. & Ur Rahman, Z.: Green finance, green energy and green revolution: An impulse response function of food security in developing economies. *Frontiers in Environmental Science*, Vol. 10 (October 2022), Article no. 982785: pp. 1–13. ISSN 2296-665X. doi: 10.3389/fenvs.2022.982785.

[13] Husain, A.A.F.; Hasan, W.Z.W.; Shafie, S.; Hamidon, M.N. & Pandey, S.S.: A review of transparent solar photovoltaic technologies. *Renewable and Sustainable Energy Reviews*, Vol. 94 (October 2018), pp. 779–791. ISSN 1364-0321. doi: 10.1016/j.rser.2018.06.031.

[14] Husain, S.; Sohag, K. & Wu, Y.-R.: The response of green energy and technology investment to climate policy uncertainty: An application of twin transitions strategy. *Technology in Society*, Vol. 71 (November 2022), Article no. 102132. ISSN 0160-791X. doi: 10.1016/j.techsoc.2022.102132.

[15] Jiang, L.; Zou, F.; Qiao, Y. & Huang, Y.: Patent analysis for generating the technology landscape and competition situation of renewable energy. *Journal of Cleaner Production*, Vol. 378 (December 2022), Article no. 134264: pp. 1–21. ISSN 0959-6526. doi: 10.1016/j.jclepro.2022.134264.

[16] Kaur, R.; Sandhu, V.; Bhabra, K. & Kaur, H.: A multivariate analysis of factors influencing green energy. *IOP Conference Series*: *Earth and Environmental Science*, Vol. 795 (2021), Article no. 012004: pp. 1–6. ISSN 1755-1307. doi: 10.1088/1755-1315/795/1/012004.

[17] Kovtun, D.; Tovmasyan, N. & Nazarov, A.: Trends and conditions for the development of green energy in the Russian Federation. *E3S Web of Conferences*, Vol. 270 (2021), Article no. 01040: pp. 1–5. eISSN 25550403. doi: 10.1051/e3sconf/202127001040.

[18] Kuzior, A.; Lobanova, A. & Kalashnikova, L.: Green energy in Ukraine: State, public demands, and trends. *Energies*, Vol. 14, Issue 22 (November 2021), Article no. 7745: pp. 1–114. eISSN 1996-1073. doi: 10.3390/en14227745.

[19] Li, J.; Dong, K.-Y. & Dong, X.-C.: Green energy as a new determinant of green growth in China: The role of green technological innovation. *Energy Economics*, Vol. 114 (October 2022), Article no. 106260: pp. 1–13. ISSN 0140-9883. doi: 10.1016/j.eneco.2022.106260.

[20] List of solar thermal power stations. Available on the Web site: http://en.wikipedia.org/wiki/List_of_solar_thermal_power_stations.

[21] Nasution, I.S.; Munawar, A.A.; Devianti; Satriyo, P.; Gunawan, H.G. & Yunus, Y.: Precision agriculture: Automated irrigation system in tandem with solar panels for melon farming cultivation. *IOP Conference Series*: *Earth and Environmental Science*, Vol. 644 (2021), Article no. 012084: pp. 1–5. ISSN 1755-1307. doi: 10.1088/1755-1315/644/1/012084.

[22] Nguyen, Q.H.; Hoai Ta, Q.T. & Tran, N.: Review on the transformation of biomechanical energy to green energy using triboelectric and piezoelectric based smart materials. *Journal of Cleaner Production*, Vol. 371 (October 2022), Article no. 133702. ISSN 0959-6526. doi: 10.1016/j.jclepro.2022.133702.

[23] Palmer, L.: Green energy financing. *Nature Sustainability*, Vol. 5, Issue 11 (November 2022), pp. 910–911. eISSN 2398-9629. doi: 10.1038/s41893-022-00972-y.

[24] Panwar, N.; Kaushik, S. & Kothari, S.: Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews*, Vol. 15, Issue 3 (April 2011), pp. 1513–1524. ISSN 1364-0321. doi: 10.1016/j.rser.2010.11.037.

[25] Pavlović, T.; Milosavljević, D. & Mirjanić, D.: *Renewable energy sources* (in Serbian). Banja Luka (Bosnia and Herzegovina): Academy of Sciences and Arts of the Republic of Srpska (ANURS), 2013. – 365 pp. ISBN 978-99976-42-41-0.

[26] Pavlović, T.; Radonjić, I.; Milosavljević, D. & Pantić, L.: A review of concentrating solar power plants in the world and their potential use in Serbia. *Renewable and Sustainable Energy Reviews*, Vol. 16, Issue 6 (August 2012), pp. 3891–3902. ISSN 1364-0321. doi: 10.1016/j.rser.2012.03.042.

[27] Pavlović, T.; Radonjić, I.; Milosavljević, D.; Pantić, L. & Piršl, D.: Assessment and potential use of concentrating solar power plants in Serbia and Republic of Srpska. *Thermal Science*, Vol. 16, Issue 4 (2012), pp. 931–945. ISSN 0354-9836. doi: 10.2298/TSCI111027100P.

[28] Reddy, V.S.; Kaushik, S.C.; Ranjan, K.R. & Tyagi, S.K.: State-of-the-art of solar thermal power plants – A review. *Renewable and Sustainable Energy Reviews*, Vol. 27 (November 2013), pp. 258–273. ISSN 1364-0321. doi: 10.1016/j.rser.2013.06.037.

[29] Rybak, A. & Rybak, A.: Analysis of the strategy for the energy policy of Poland until 2030 implementation effects in the aspect of environmental protection taking into account the energy security of Poland. *IOP Conference Series*: *Earth and Environmental Science*, Vol. 261 (April 2019), Article no. 012044: pp. 1–12. ISSN 1755-1307. doi: 10.1088/1755-1315/261/1/012044.

[30] Rybak, A. & Włodarczyk, E.: Energy policy until 2040 and the future of hard coal in Poland. *IOP Conference Series*: *Earth and Environmental Science*, Vol. 609 (December 2020), Article no. 012009: pp. 1–9. ISSN 1755-1307. doi: 10.1088/1755-1315/609/1/012009.

[31] SMA GmbH from Kasel (Germany). Available on the Web site: https://www.sma.de/.

[32] Solarna elektrana manufactured by Gradjevinski klaster Dundjer from Niš. Available on the Web site: http://www.dundjer.co.rs/solarna-elektrana/.

[33] Top 5 largest solar power plants of the world. Available on the Web site: https://www.solarinsure.com/largest-solar-power-plants.

[34] Topçu, Y.I. & Ulengin, F.: Energy for the future: An integrated decision aid for the case of Turkey. *Energy*, Vol. 29, Issue 1 (January 2004), pp. 137–54. ISSN 0360-5442. doi: 10.1016/S0360-5442(03)00160-9.

[35] Torshizi, M.V. & Mighani, A.H.: The application of solar energy in agricultural systems. *Renewable Energy and Sustainable Development (RESD)*, Vol. 3, Issue 2 (June 2017), pp. 234–240. ISSN 2356-8518. doi: 10.21622/RESD.2017.03.2.234.

[36] Vaidya, A.S.: A study of solar electric tractor for small scale farming. *International Journal of Science and Research (IJSR)*, Vol. 8, Issue 3 (March 2019), pp. 1255–1259. ISSN 2319-7064.

[37] What is green energy? (Definition, types and examples). Available on the Web site: https://www.twi-global.com/technical-knowledge/faqs/what-is-green-energy.

[38] Xie, C.Y. & Zhou, J.: Assessment of provincial total factor green energy efficiency in China: Based on super-SBM model. *IOP Conference Series*: *Earth and Environmental Science*, Vol. 495 (2020), Article no. 012017: pp. 1–7. ISSN 1755-1307. doi: 10.1088/1755-1315/495/1/012017.

[39] Zainol Abidin, M.A.; Mahyuddin, M.N. & Mohd Zainuri, M.A.A.: Solar photovoltaic architecture and agronomic management in agrivoltaic system: A review. *Sustainability*, Vol. 13, Issue 14 (July 2021), Article no. 7846: pp. 1–27. eISSN 2071-1050. doi: 10.3390/su13147846.

[40] Zeng, S.-H.; Tanveer, A.; Fu, X.-L.; Gu, Y.-X. & Irfan, M.: Modeling the influence of critical factors on the adoption of green energy technologies. *Renewable and Sustainable Energy Reviews*, Vol. 168 (October 2022), Article no. 112817: pp. 1–14. ISSN 1364-0321. doi: 10.1016/j.rser.2022.112817.