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Basic principles of the fourth industrial revolution in the logistics activity of small and medium enterprises

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Abstract: *This article focuses on the basic principles of the fourth industrial revolution in the logistics of small and medium enterprises. The development of the Fourth Industrial Revolution and its real application in practice and business pose extremely responsible tasks to logistics. It already has not only an independent role in this whole process of restructuring and transition of conventional logistics activities to those related to intelligent activities, but also a mandatory functional share in the development of all activities related to the Fourth Industrial Revolution.*
KEYWORDS*: INDUSTRY4.0; INTERNET OF THINGS; IOS; CYBER-PHYSICAL SYSTEMS; INTELLIGENT MANUFACTURING; CLOUD PRODUCTION, ETC.*

INTRODUCTION

The scope of the Fourth Industrial Revolution is not limited to intelligent and interconnected machines and systems. There are waves of new breakthroughs in areas from gene sequencing to nanotechnology and from renewable energy sources to quantum computers. The fusion of these technologies and their interaction in the physical, digital and biological fields make the fourth industrial revolution radically different from previous revolutions.
Emerging technologies and far-reaching innovations are spreading and penetrating much faster and wider than the previous three, which continue to unfold in some parts of the world to this day.

1.Stages of the industry

There are four different industrial revolutions that the world has either experienced or continues to experience today. The word "revolution" means abrupt and radical change. In the course of history, revolutions occur when new technologies and new ways of perceiving the world cause a fundamental change in economic systems and social structures. In Figure 1 it shows the stage of the industry.

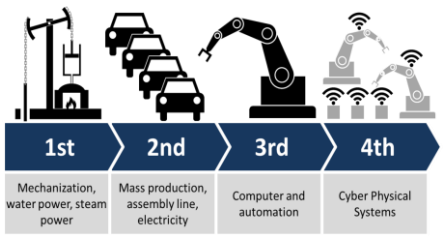


Fig.1 *Stages in the industry*.[18]

The first industrial revolution
The first industrial revolution took place between the late 1700s and the early 1800s. During this time, production has evolved from a focus on manual and animal-assisted manual labor to a more optimized form of human labor through the use of water and steam engines and other machine tools.

Second industrial revolution
At the beginning of the 20th century, the world entered a second industrial revolution with the introduction of steel and the use of electricity in factories. The introduction of electricity has enabled manufacturers to increase efficiency and helped factory machines to be more mobile. During this phase, mass production concepts were introduced as a way to increase productivity.

Third industrial revolution
In the late 1950s, a third industrial revolution slowly began to develop as manufacturers began to incorporate more electronic and computer technology into their factories. During this period, manufacturers began to experience a shift that focused on analog and mechanical technology and on digital technology and automation software.

Fourth Industrial Revolution or Industry 4.0.
The fourth industrial revolution is at the highest stage of automation and data exchange in industrial activities. This includes the creation of physical Cyber systems that present a network of machines and people in real and virtual form throughout the sustainability chain, a digital approach to real-time information exchange and analysis, transparency and efficiency of the processes offered by agents and products for customers.
Industrial special activities, including “Smart factories have a cyber functional structure implemented through the Internet of others and Internet services.
Manufacturing companies operate in conditions of increasing global competition, which requires a sharp reduction in time and costs in the production of products. This is one side of the problem, the other is the growing demand for individualized technical products and services, more efficient use of resources and greater flexibility of production processes. To meet these challenges, industrial companies have begun to look for new approaches to increase their productivity and process flexibility. Linking technology to business processes by applying a high degree of automation could answer these questions. At the same time, conditions were created for the rapid development of information and communication technologies and their application in industry. Thus, the connection of machines and electronics in networks allowed them to work autonomously. New technological opportunities and innovations in the fields of machine-machine communication, human-machine communication, human-human communication have allowed the company-consumer relationship to develop in a new, more efficient context. The conditions were created for defining a new industrial development, or the so-called Fourth Industrial Revolution. It is essentially the trend for digital development of the industry[2,10].

According to Schwab, there are at least three reasons to say that the changes in today's world are a new revolution, not a continuation of the Third. These are the speed with which the way of production and consumption, the scope of the changes and their systemic impact change. As a result, the possibilities for billions of people with electronic devices with unprecedented capabilities for processing, storing and accessing knowledge are limitless. All of these opportunities will be multiplied by breakthroughs in emerging technology sectors such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy conservation and quantum computing. For example, artificial intelligence now surrounds us everywhere, from self-driving cars and drones to virtual assistants or software that translates text or invests our money. In recent years, we have seen impressive advances in artificial intelligence, such as increasing computing power or the collection of vast arrays of data, from the software used to create new drugs to algorithms for predicting our cultural interests. For example, artificial intelligence now surrounds us everywhere, from self-driving cars and drones to virtual assistants or software that translates text or invests our money. In recent years, we have seen impressive advances in artificial intelligence, such as increasing computing power or the collection of vast arrays of data,

from the software used to create new drugs to algorithms for predicting our cultural interests.

2. Principles of Industry 4.0.

The principles of Industry 4.0 are characterized by interoperability and interconnection, information transparency e.g. virtualization,decentralization and autonomous decisions, real-time capability, technical assistance and service orientation and finally, modularity

- ***Internet of things***

By the Internet of Things we mean the Internet of the components of the cyber physical system (CPS), or considered in the cybernetic system aspect, the components appear as subsystems of the system (CPS). The components in this case are; intelligent machines, embedded self-regulating systems, hardware, software, etc. uniquely addressed objects and networks that intelligently interact with each other to achieve a common goal. Therefore, the Internet of Things (Internet der Dinge) describes a complete network of embedded systems with objects of everyday life, production, infrastructure or machines via the Internet, which have uncontrolled human communication about the state of the system and perform actions (component-to-component communication)[14,15]. Based on the definition of CPS "things" and "Objects" can be understood as CPS. Therefore, the Internet of Things can be defined as a network in which CPSs cooperate with each other through unique targeted schemes. In Figure 1 it shows internet of things.



Fig.2 *Internet of things*.[17]

- ***Internet of Services (IOS)***

The Internet of Services (IOS) is in fact the ability of "service providers" to offer their services through the Internet. IOS consists of the participants in the service, namely: the infrastructure for services, business models and the service providers themselves. that this concept will be transferred from single factories to entire networks of value-added sites in the future.Factory can be another step forward and offer special production technologies, not just types of production.These production technologies will be offered above iOS and The idea of IOS was implemented in a project called SMART FACE within the "Autonomics for Industries 4.0" program initiated by the Federal Ministry of Economics and Energy. It is developing a new distributed production control for the automotive industry.This allows the use of modular mounting stations, which can be flexibly modified or extended. Transportation between collection points is provided by automated controlled vehicles. Both collection points and automated vehicles offer their services through IOS[14,15]. Information and communication technologies, on the other hand, form a solid foundation on which new innovative solutions can be created. Figure 3 it shows the Internet of services.



Fig.3 *Internet of services* .[16]

- ***Cloud production system***

In the cloud production system shown in Fig. 4, the services form the service network and the cooperation network. Network performance can affect the cloud production system. Researchers.[14,15]



Fig.4 *Cloud production system*.[19]

Conclusion

The Industry 4.0 is a challenge for the modern industrial world, which is related to solving a wide range of issues related to its application, namely:

1. Establishment of a supranational program for digitalization of the processes and activities related to that Industry 4.0, exceeding the borders of the current countries.
2. Full unification and standardization of the information systems related to that Industry 4.0.
3. Creating a global digital market.
4. Providing investments for the development of that Industry 4.0

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Innovations and innovative potential in the context of new trends in business management in Slovakia

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Abstract: *The importance of innovation is increasingly emphasized and understood these days to ensure the future growth of enterprise and its survival. Innovations allow companies to coordinate their operations with changes that occur in their environment, changes in the market and with the ever-changing needs of customers. Innovation is understood as a very important factor of organizational performance and its survival and prosperity in a competitive environment. The company's innovative potential represents the company's ability to implement all innovation processes and defines how effectively the company can not only create but also use its innovations. The company's innovation and innovative potential are the most important and complex issues that companies currently face and is the key to the success of all organizations. The competition that companies have to compete with is strong and over time the customer requirements themselves are becoming more and more demanding, so it is increasingly important for the company to be aware of its innovative potential, which it can develop by introducing and using new innovations. It is important for companies to be able to anticipate and address the challenges that come their way and transform them into creative and innovative solutions and to respond effectively to unforeseen events. The main aim of the paper is, based on the analysis of theoretical knowledge, to identify innovation and innovative potential in business management reflecting current changes and challenges in the environment, and to assess their importance by Slovak companies.*

Keywords*: INNOVATION, INNOVATIVE POTENTIAL, BUSINESS MANAGEMENT TRENDS*

1. Introduction

All societies and the economy in general are thriving on innovation. Whether it is because of new products, new processes, or new materials. The reason and the main motive are associated with increasing profits, either by reducing costs or increasing revenue. In a rapidly changing world with ever-evolving technologies and increasing competition, a company needs to come up with new innovations that not only meet customer needs but also increase the company's overall efficiency.

Organizations are including the term innovation in their vision, mission, and objective statements. Innovation should be thought of as both an outcome and process. Organizations defining innovation as only one of these will fall short in its pursuit. The output typically associated with innovation is the introduction of new products and new services, which exemplifies what is termed product innovation. Innovation as a process represents the way in which innovation is and should be organized so that these outcomes can come to fruition [1]. Innovation is often happened using open technologies and high-quality open resource and relies on a different kind of knowledge and information system. Knowledge management is the most important part of the innovation [2]. The increasing complexity of products and services, shorter life cycles, and rapidly changing market demands require new or different capabilities and management practices to successfully develop innovations and sustain a company's competitive advantage [3]. In innovation evaluation in practice, the importance of measuring innovations is increasingly gaining the attention of managers and consultancies [4]. Narrowly connected with the double challenge represented by the global environmental crisis and the new wave of technological advancements commensurate with the fourth industrial revolution is the management of risks and generation of a new incumbent, that is responsible innovation [5].

Keeping active innovative activity ensures the overall development of entrepreneurship, as well as improving or maintaining its competitiveness [6]. In the modern economy, the definition of innovation potential is not entirely precise, and precisely because of this, there is no adequate approach to how to quantify it. The category innovation potential can be treated as a capability of system to transformation of the actual order of things in a new condition for the purpose of satisfaction of the existing or again arising requirements. Therefore, innovative potential is characteristic of a capability of system to change, improvement, progress [7]. Innovative potential interpretation variants were deduced as an innovation activity result in confirming the cyclicality of innovation process and the innovation lifecycle, as innovation activity result [8].

2. Results and Discussion

We consider the work of the consulting company Bain & Company, which since 1993 has been conducting a worldwide survey called "Management Tools & Trends", which focuses on monitoring the behaviour and attitudes of managers, the use of individual management methods and tools and assessment their effectiveness. The survey focuses on selected management tools and trends, which are specified in terms of their timeliness, measurability, and relevance to senior management. The aim of managers worldwide is to maintain and develop companies in an environment of constant change and a rapidly changing environment. Managers thus use more targeted approaches with respect to management tools, which is the application of a smaller number of individual tools to maintain their income and increase profits. The current economic environment brings new challenges for business managers, but at the same time they must also consider possible risks. Factors such as the demographics of emerging economies, the aging of the population and the scarcity of resources are accelerating structural changes in market equilibrium, which, in addition to business opportunities for growth, also entails associated risks. Examples include the introduction of digital technologies, which allow businesses to expand into new markets but also bring instability, macroeconomic disruptions in the form of cyber-attacks, which are gradually becoming a risk for all businesses using digital technologies. The international survey (N= 1067) shows the results concerning the opinions of managers in the field of managerial trends. The surveyed managers believe that their company will grow in the next period, as evidenced by the fact that up to 75% of them declare that the ability to adapt to change is their main competitive advantage. Inquired managers (74%) consider the introduction of innovation to be more important than reducing costs in the long run, and 59% believe that there are significant opportunities to improve sustainability and profitability [9].

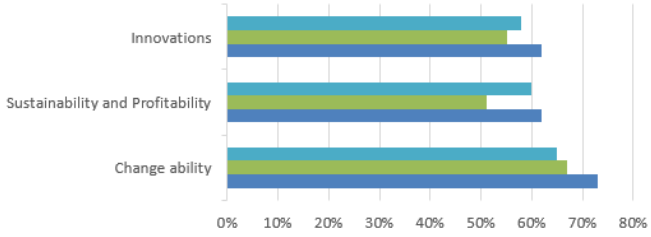
According to the most recent survey (N= 1268) 66% of managers think that digital disruptions and software solutions are rapidly changing the rules of competition. More than half of managers (59%) think that they could dramatically boost innovation by collaborating with outsiders, even competitors [10].

The object of our research was formed by a sufficiently large and representative sample of companies operating in the territory of the Slovak Republic. The respondents, due to the focus of the research, were mainly company executives, directors, and managers

at least middle management. To examine how companies, perceive the current market situation, as well as their company and their position in the market, we found out the following statements representing managerial trends. In evaluating the individual statements, the statements with which the managers most often agreed were as follows. Most companies, up to 68%, agreed that "the ability to adapt to change is their significant competitive advantage". Half of the respondents also agree with the statement and "believe that there are significant opportunities to improve sustainability and profitability". The third statement, with which companies most often agreed, concerned "innovations that are more important for companies in the long run than reducing costs" (40%). Extremely few businesses (only 4%) are concerned about a cyber-attack on their business. The next section compares the rate of application of the selected three management trends considering the identification data on companies, namely: business sector, size, and capital structure.

We have classified companies according to the focus of their business activities on manufacturing companies, trading companies and service companies. The ability to adapt to change, that is company´s significant competitive advantage, was agreed the most by trading companies (73%). The statement about the innovations was agreed by 62% trade companies, 58% manufacturing companies, and 55% service companies.

Table 1: *Management trends applied by different business sector enterprises.*



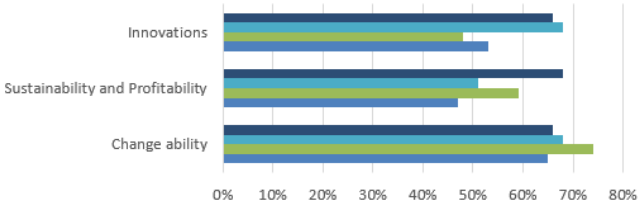
	Change ability	Sustainability and Profitability	Innovations
Manufacturing	65%	60%	58%
Services	67%	51%	55%
Trade	73%	62%	62%

Source: own processing

Most often, the size of the company is measured based on the number of employees, annual turnover, and annual balance sheet. These criteria are based on the classification recommended by the European Commission (European Commission Recommendation No. 2003/361 / EC, valid from 1 January 2005). Similarly, we researched the size category of companies based on the three criteria, but since several answers were controversial, we proceeded to the size categorization of companies based on the number of employees. The management trend, that innovations are more important for companies in the long run success than reducing costs, agreed 66% of the large companies (above 250 employees), 68% of medium-sized companies (above 50, up to 250 employees), 48% of small companies (above 10, up to 50 employees), and 53% micro companies (up to 10 employees). Ability to adapt to change as significant competitive advantage was comparable in all size categories, mostly agreed by small enterprises.

In the following criteria, we examined the identification with selected management trends according to the presence of foreign capital in the ownership structure of companies. Here a significant difference in the perception of innovation can be observed between 100% Slovak (51%) and mostly Slovak (54%) versus mostly foreign and 100% foreign companies (identically 70%). 77% mostly Slovak companies believe that there are significant opportunities to improve sustainability and profitability and 85% mostly foreign companies think that the ability to adapt to change is their significant competitive advantage compared to just 31% mostly Slovak companies that think the same.

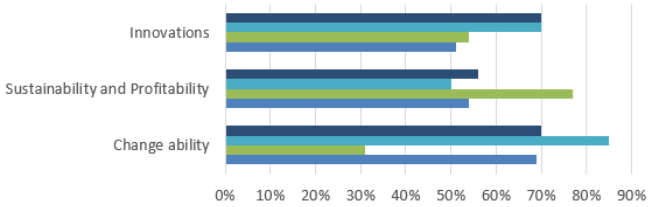
Table 2: *Management trends applied by different sized enterprises.*



	Change ability	Sustainability and Profitability	Innovations
Large enterprises	66%	68%	66%
Medium-sized enterprises	68%	51%	68%
Small enterprises	74%	59%	48%
Micro enterprises	65%	47%	53%

Source: own processing

Table 3: *Management trends applied by different capital structured enterprises.*



	Change ability	Sustainability and Profitability	Innovations
100% foreign	70%	56%	70%
mostly foreign	85%	50%	70%
mostly Slovak	31%	77%	54%
100% Slovak	69%	54%	51%

Source: own processing

Across all industries and regions, digital technology is a dominant factor. Two-thirds of executives report that digital disruption and software solutions are rapidly changing the rules of competition in their industries. And they are making good use of tools aimed at helping them address these shifts. Use of digital transformation is increasing, and respondents report high levels of satisfaction with it. Managers are upbeat about their ability to capture data and analyse it successfully. Despite other evidence that many companies struggle to get the most out of analytics, more than half of respondents to this survey claim they are able to capture and exploit the full value of data from all corners of their companies. This is a time of rapid change in business and markets, with new competitors emerging every day and customers untethered from traditional loyalties. Respondents feel both challenged by this environment and less capable of handling change. In 2014, 75% of respondents felt that their ability to adapt to change was a significant competitive advantage. Today, only 56% feel that their companies adapt to change faster and better than competitors do [9,10]. Based on these results, we have researched three management tools, such as manifestations of innovation and innovative potential, namely: digital transformation, big data analytics, change management.

Digitalization and, later, digital transformation are drivers for changes in the corporate world, because they establish new technologies based on the internet with implications for society as a whole [11]. Digital technologies contribute to the transformation of large parts of our economy and society. Also, the nature of innovation itself has undergone a digital transformation [12]. Big data analytics is increasingly becoming a trending practice that generates an enormous amount of data and provides a new opportunity that is helpful in relevant decision making [13]. Through focused deployment of big data analytics, firms can sense emerging opportunities and threats, generate critical insight, and adapt their operations based on trends observed in the competitive environment [14]. Managing change is not just important but crucial

for the success of the final product of companies [15]. Change management is the area of study that aims to facilitate the transition of individuals, teams, or the whole organization by managing them. The key issue in successfully implementing change is a matter of successfully changing the organizational culture, so that on-going change becomes the accepted norm [16].

When applying selected three innovative tools, we determined the satisfaction of respondents with individual tools. Only respondents who used the tool answered the question about the satisfaction assessment. Satisfaction was rated on a scale of 1 to 5, with a value of 5 meaning that they were very satisfied with the tool and a value of 1 indicating that they were very dissatisfied. Fig. no. 1 shows the examined 3 innovative tools in management, while the vertical axis shows the total use of this tool in % and the horizontal axis represents the average satisfaction of respondents evaluated on a point scale. In general, it can be stated that the respondents were satisfied with the tools used, as the average satisfaction rates were above the level of 3 points (when the respondent was neither satisfied nor dissatisfied) upwards. Respondents were the most satisfied with digital transformation tool, which rated an average of 3.62 points. The change management tool was evaluated with an average of 3.60 points and was the most widely used (47%). The big data analysis tool was evaluated with an average of 3.50 points and usage rate was 30%.

In the case of the digital transformation tool, respondents often considered it costly without a positive result, especially in the impact of global solutions on the local market or organization. The big data analytics tool was also assessed as time-consuming compared to the added value it brings to the company, complications are also caused by the diversity of business models and the limited ways and possibilities of using this data.

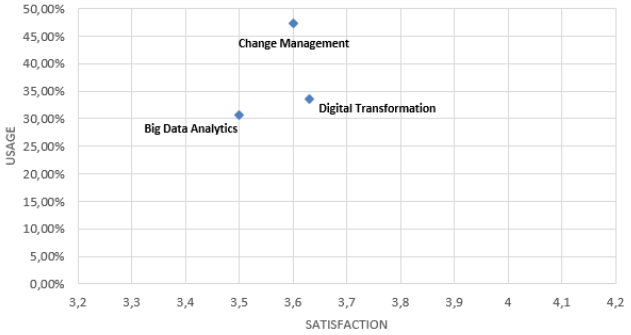


Figure 1: *Innovative management tools- usage and satisfaction.*

Source: own processing

In the following graph (Fig. no. 2) we can see the rate of usage selected innovative management tools related to the size category of the company, which we consider as an important aspect.

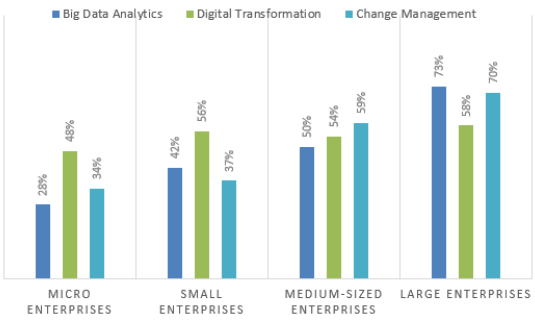


Figure 2: *The rate of usage selected innovative management tools.*

Source: own processing

With a larger size category, a higher rate of usage of individual innovative management tools can also be seen. All three tools researched are most widely used by large companies, with more than 250 employees.

3. Conclusion

Despite the ever-increasing popularity of the field of innovation, which companies cannot avoid, innovation is often perceived by companies as something risky and unpredictable. However, if a company wants to succeed and keep up with rapid times and technological change, then innovation is something it must learn to work with. Today, new and improved products and services are constantly coming to the market thanks to certain trends that have accelerated this process. Therefore, companies' products and services are becoming obsolete much faster than in the past. It is essential for companies to innovate and create something new for society in order to gain a foothold in a tough competitive market.

The ever-changing environment in the economy calls into question traditional economic and business concepts. There were times when innovative trends in the management of organizations were applied only by the largest companies and those that led to change. Gradually, however, their knowledge and use becomes one of the requirements for the survival of the company in the market. Managers and entrepreneurs need to look ahead, anticipate change and follow a strategy to proactively and successfully overcome the turbulence caused by change. Innovative trends in management represent effective management tools that serve to identify new opportunities, bring changes to the business to achieve continuous improvement in the way an existing activity, function or process is performed. In general, it is necessary to prioritize in the management so that the company avoids being swallowed with information and does not lose contact with the vision and goals. This also applies to the selection of control methods. This means that they are not bad methods, just appropriate and less suitable for company´s goals. At the same time, the dynamics of time determine that information and outputs are old even during data acquisition, analysis and conclusion. Another aspect of decision-making and management is risk estimation and risk acceptance.

4. Acknowledgment

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Innovation as a necessary factor in the development of the gold mining industry in Azerbaijan

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Abstract: *This article presents analysis of the current situation of the gold mining industry of Azerbaijan. The analysis is performed a review of the main individual problems of the country's gold mining industry. It is found that the gold for Azerbaijan is a priority and highly liquid type of strategic minerals along with fuel and energy raw materials and some other important minerals.Also, it is noted that the gold mining industry of Azerbaijan, as a young branch of the economy, has a promising future. And the study of innovation ways of development in this industry is of particular importance for the republic.*
KEYWORDS*: GOLD MINING, GOLD DEPOSITS, GOLD EXPORT, GOLD PRODUCTION, SWOT ANALYSIS, OPPORTUNITIES AND THREATS*

1. Introduction

Development of the gold mining industry in Azerbaijan contributes to the emergence of one of the most strategically important sectors of the republic's economy. Azerbaijan has a large developed and prepared reserve base of gold, significant forecast resources for expanded reproduction of reserves. According to the indicators of the Ministry of Ecology and Natural Resources of Azerbaijan, gold reserves in the country, taking into account all discovered deposits, amount to 1,500-2,000 tons.

Today, when Azerbaijan is faced with the task of modernizing and diversifying the national economy through the advanced development of the non-oil sector, the revival of the gold mining industry entails the need for its development in market conditions.

Azerbaijani gold mining industry is improving every year, the standards of work are changing, new deposits are being developed, the latest equipment and technologies are being introduced, and a modern system of industrial, financial and trade relations is applied.

At the same time to maintain the gold mining in the region with the development of new industries and fields of activity requires a set of technical, technological, institutional and organizational innovation measures. Unsatisfactory level of scientific, innovative solutions developed for the needs of the gold mining industry significantly complicate the increase in the competitiveness of this industry.

2. Importance of the mineral resource base of gold in the modern economy of the republic has been determined.

It is indicated that for Azerbaijan the presence of mineral resource base of gold is extremely important in strengthening economic and defense security, as well as ensuring the balanced development of economic sectors.

Azerbaijan is one of the few countries in the world with sufficient reserves of gold, therefore, the efficient exploitation of its deposits and the rational use of the mined metal determine the functioning and development of the republic's economy. Although the Republic of Azerbaijan cannot be attributed to the world leaders in gold reserves, there are a number of deposits that are unique in terms of volume on its territory [1].

Azerbaijan needs to strengthen its economic and defense security. The defense and space industry, industrial and civil construction, mechanical engineering and shipbuilding traditionally consume gold for the production of products of extremely high reliability. Gold as a metal has found wide application in such industries as instrumentation, nuclear industry, medicine, electronics [2].

Its role is also exceptional in the jewelry business. Thus, a significant amount of gold is used to make dentures, coins and medals, jewelry, gilding, and more [3].

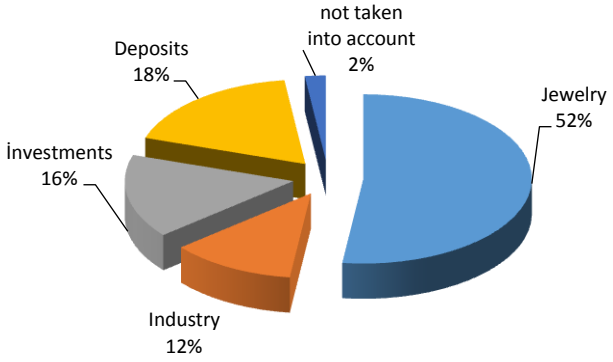


Fig. 1. *Structure of world gold consumption, in % [4]*

Having a sufficient mineral resource base of gold means being the owner of gold reserves, which are on the balance of the central bank or finance ministry and serve to stabilize the money supply, settlements with foreign countries and payments of public debt. As part of the country's gold and foreign exchange reserve, gold is a testament to the economic power of the state [5].

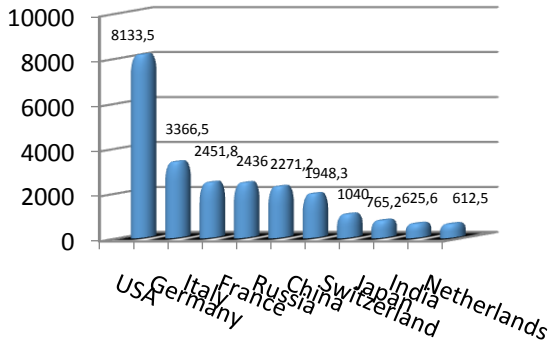


Fig. 2. *Ten countries with the largest gold reserves in 2020, tons*

Azerbaijan is also no exception - it is gradually replenishing its gold reserves and intends to continue increasing. Share of pure gold in Azerbaijan's strategic international reserves amounted to more than 10% at the end of 2019

3. Econometric assessment of the gold mining industry of the republic showed that there is a high correlation between gold production and GDP in Azerbaijan.

Since gold production in the mining industry as an economic activity affects GDP growth, it is especially important to assess the relationship between these indicators and determine the

development prospects. Here the model of correlation-regression to assess the relationship between GDP, which is a key indicator of economic well-being of society, and income from gold production [6].

Table 1.*Main indicators of the mining industry in Azerbaijan in 2009-2019 and GDP, in mln AZN [7]*

Years	Investment in fixed assets	Volume of gold production	GDP
2009	2088	8,82	35601,5
2010	2952	65,89	42465
2011	3244	70,85	52082
2012	3857	66,22	54743,7
2013	5095,2	57,3	58182
2014	5947,9	59,48	59014,1
2015	7145,1	85,63	54380
2016	8576,7	121,94	60425,2
2017	8428,9	254,92	70135,1
2018	5702,3	240,98	79797,3
2019	5288,2	282,51	81681,0

To conduct a regression analysis of the relationship between the impact of total gold production on GDP in Azerbaijan in 2009-2019, according to Table 1, a ready-made mathematical software package EViews was used. To this end, gold production in the mining industry as a causal factor is denoted as X, and GDP as an effective factor is denoted as Y, and using the EViews-10 software package, we obtained the following result based on the data in Table 1.

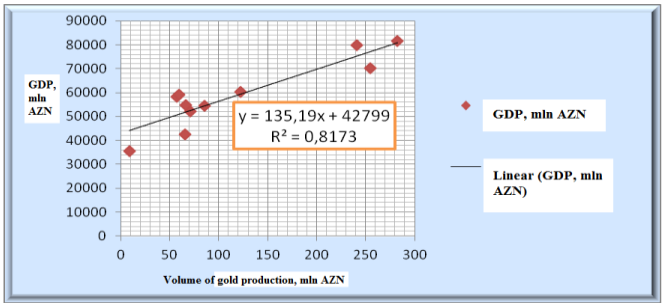


Fig. 3. *Relationship between GDP and total gold production in the mining industry in Azerbaijan [7]*

As can be seen from the above, there is a high direct correlation ($R_{yx} = 0,82$) between the Y and X variables on the Chadok scale (0.7-0.9) [8]. Also, using the F-Fisher and Durbin-Watson (DW) tests, it was proved that the regression equation as a whole is statistically significant and the constructed model (1) is adequate.

If we calculate the coefficient of elasticity in accordance with the coefficient of free variables in the relationship equation and calculate the average values of the volume of GDP with a causal factor for the periods under study, we get the following result. If we calculate the coefficient of elasticity in accordance with the coefficient of free variables in the relationship equation and calculate the average values of the volume of GDP with a causal factor for the periods under study, we get the following result.

$$\mathbf{E_{ВВП}} = \frac{\alpha \times \bar{x}}{\bar{Y}} = \frac{135,193 \times 74,37}{58955,17} = \mathbf{0,170541\ (1),}$$ where

α – coefficient of the dependent variable in the regression equation,

$\bar{x}$ – average free variable value

$\bar{Y}$- average value of the dependent variable

According to the calculation, an increase in total gold production by 1% in the mining industry of Azerbaijan leads to an increase in GDP by 0.171%.

4. SWOT analysis of the gold mining industry of the country revealed and indicated a set of necessary strategic alternatives for the economic activities.

SWOT analysis characterizing the strengths and weaknesses of the gold mining industry in Azerbaijan allowed formulate proposals for overcoming threats and using the opportunities of the environment, in particular, the transition to innovative technological development, expanding the resource base, increasing investment attractiveness.

Table 2. *SWOT analysis of the gold mining industry in Azerbaijan*

Strengths (S)	**Opportunities (O)**
Rich mineral resource base of gold	Discovery of new objects
Great potential for growth in the mineral resource base	Increase in production due to the use of new extraction technologies
Availability of a huge systematized database from the Soviet times	Increase in the share of ore gold
Relatively low production cost	Improvement of the investment climate in the industry
Weaknesses (W)	**Threats (T)**
The location of deposits in remote and hard-to-reach places, therefore, companies need to purchase fuel, food, overalls, spare parts and components, equipment and everything necessary for production in advance.	Late delivery of materials, fuel, spare parts and components, equipment and other resources. And, accordingly, the increase in prices for the resources provided.
Seasonality of work associated with the location of enterprises in regions with unfavorable weather conditions	The need for preliminary preparation for the production season.
Deficit of qualified personnel	Introduction of legal restrictions
Infrastructure restrictions	Failure by the miners to fulfill their ambitious investment plans
High capital intensity	Facing environmental challenges

Specificity of the gold mining industry has another important feature related to the environment. Development of gold deposits and their processing can be accompanied by significant environmental degradation [9]. Gold mining, if the operating rules are not followed, leads to water pollution, soil erosion and the emission of greenhouse gases. The latest technologies that contribute to the safe conduct of gold mining will play a huge role in protecting the environment.

5. Conclusions

Gold plays a huge role in ensuring economic and defense security, which Azerbaijan is in dire need of today. All products of such strategic industries as defense, space, engineering, shipbuilding are traditional consumers of gold, which requires the intensification of the work of gold mining. Gold mining also creates demand for the products of dozens of related industries, for example, mining engineering, production of drilling and power equipment, etc. In particular, gold for Azerbaijan is a priority and highly liquid type of strategic minerals along with fuel and energy raw materials and some other important minerals.

Interest of foreign investors in the gold deposits of the Republic of Azerbaijan and their arrival in such a closed industry in 90s became significant in the process of integrating the domestic gold mining business into world economic processes.

Consequently, the development and pilot testing of various options for innovative technologies for gold production is currently an urgent topic for maintaining the gold mining industry in Azerbaijan.

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Covid-19 impact on the going concern assessment – the management perspective

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Abstract: *The pandemic outbreak has significantly impacted many businesses and their ability to continue operating as a going concern. Going concern is a basic accounting principle as well as one of the fundamental assumptions under the International Financial Reporting Standards. The management is responsible to determine whether the going concern assumption is relevant in the preparation of company's financial statements. With the progress of the novel coronavirus the focus on whether an entity is a going concern should be heightened. Taking into consideration the continuing uncertainty in the Covid-19 environment, the aim of the paper is to discuss the challenges through the lens of the company's management in the assessment of the going concern assumption. Few questions that should be considered when performing the analyses as well as some of the factors that contribute to a robust assessment are outlined. A special attention is given to disclosure requirements and their improvement in the Covid-19 context.*

Keywords: COVID-19, GOING CONCERN, UNCERTAINTY, DISCLOSURES, MANAGEMENT PERSPECTIVE

1. Introduction

Going concern is a basic accounting principle and one of the fundamental assumptions under the International Financial Reporting Standards (IFRSs). Referring to the latter, it is a responsibility of the management to assess it at the end of the reporting period when preparing company's financial statements. In case of material uncertainties related to the ability of the business to continue its operations as a going concern, the board should disclose those events or conditions. Moreover, it should take into consideration all the available information about the future that might cast significant doubt upon entity's ability to continue as a going concern.

The pandemic outbreak has significantly impacted many businesses and the consequences of Covid-19 might comprise of operational shutdowns, reduced demand of products/services, higher levels of indebtedness, reduced access to additional financing, etc. that deteriorate entity's operating results and financial position [1]. From the management's perspective, it is a challenge that should be approached accordingly and properly communicated with investors who seek clarity and it is important for them to receive complete information of a high-quality about company's future prospects and its ability to navigate through such uncertainty [2], [3]. The boards should disclose detailed and useful information in entity's financial statements and the going concern issue is one of the most impacted. Its assessment became a more complex task with the progress of the novel coronavirus [4].

Motivated by the new challenges in the assessment of the going concern assumption caused by the continuing uncertainty in the Covid-19 environment, the aim of the paper is to discuss them through the lens of the company's management and its responsibilities based on the requirements of IFRSs as the applicable financial reporting framework. Few questions that should be considered when performing the analyses as well as some of the factors that contribute to a robust assessment are outlined. Disclosure requirements and their improvement in the Covid-19 context are also highlighted.

2. Regulation on the going concern assumption

Management's responsibilities encompass not only the assessment of entity's ability to continue as a going concern, but also making and disclosing significant judgements related to the uncertainty associated with the future outcomes of events or conditions, the impact of external factors on entity's business and its future.

Going concern assessment requirements are provided in IAS 1 *Presentation of Financial Statements*, paragraphs 25-26. They are summarised on figure 1.

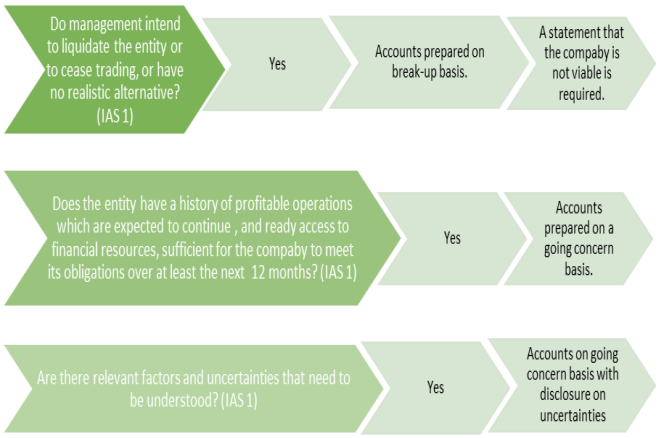


Fig. 1 *IFRSs regulation on the going concern, based on [4]*

If the management has no intention to liquidate the business or cease trading in the foreseeable future and there are no events or conditions that may cast significant doubt upon the entity's ability to continue as a going concern, then company's financial statements should be prepared on a going concern basis. According to IAS 1, paragraph 26, in all other cases, management should consider a variety of factors related to current and expected profitability, debt repayment schedules and potential sources of replacement financing in determining whether the going concern basis is appropriate [5]. For example, such factors might be any restrictions on entity's activity, imposed by the government as part of the Covid-19 measures, changes in customer behavior as a response to the pandemic, and other structural market changes in the longer-term [6], deferred payments of taxes, any changes in staffing levels and related staff costs as well as any government mitigating schemes [7]. For understanding any uncertainties and factors that might affect the board in assessing this fundamental assumption, relevant disclosures should be provided. Among the factors the management may need to consider in case of continuing uncertainties are the effects of any temporary shut-down or curtailment of the entity's activities, possible restrictions on activities that might be imposed by governments in the future, the continuing availability of any government support and the effects of longer-term structural changes in the market (such as changes in customer behaviour).

IAS 1 requires all sources of estimation uncertainties to be disclosed. In regard of the going concern assessment, this implies providing information about the amounts that might lead to a material adjustment to the carrying amounts of assets and liabilities within the following reporting period. Moreover, entities are required to disclose some details of the nature and carrying values of those assets and liabilities at the end of the financial period.

When company's financial statements are not prepared on a going concern basis, this fact should be disclosed together with the applied alternative reporting basis. Information supporting such decision should be also revealed.

Company's management will be responsible for assessing entity's ability to continue as a going concern even if there are no explicit requirements but the going concern is still a fundamental assumption under the applicable financial reporting framework.

3. Questions to be considered from the company's management

There are few issues in respect of the going concern assessment that company's management should approach with due care in times of evolving uncertainty caused by the pandemic outbreak. Certain sectors are more affected as their business models are significantly disrupted by the spread of Covid -19. It has been highlighted that the board's decision should be grounded on relevant factors as the industry and geographic area of operations, customers' and suppliers' financial position, entity's liquidity and solvency [8], access to financing, terms and timing of funding, etc. Those factors might be impacted by expected future lockdowns, the government and market responses, for instance the short-term funding schemes provided by the government.

First, the management should identify all the risks and uncertainties caused by the global pandemic to the business, including entity's liquidity and solvency risks. The next step implies budgets' revision to guarantee their relevance in the current evolving environment. Further, the forecasts need to be revised and updated based on different scenarios regarding forecast sales, gross margins and changes in working capital. Sources of finance should be reassessed together with any covenant breaches, if applicable. In addition, management's plans for business restructuring or market expansion, new financing or restructuring of current debt is advisable to be reconsidered in light of the Covid-19 challenges and their impact on the global economy. [9]

The useful hint for assessing the adequacy of management assessment on the going concern are the auditors' expectations, set out in the auditing standard IAS 570 *Going concern* and we will change the lens for a while and for the sake of a more exhaustive discussion on the issue. The auditors' expectations where there are events or conditions that may cast doubt on company's ability to continue as a going concern as is the case of the pandemic outbreak implications on business, include the following:

- the events and conditions that might impact and cast doubt on entity's ability to continue operating as a going concern
- how the management plans to deal with such events and conditions
- if there is a material uncertainty in regard of those events and conditions, this fact accompanied by relevant information should be disclosed
- in case of identified material uncertainty about entity's ability to realise its assets and discharge its liabilities in the normal course of business operation, this fact needs to be disclosed [10]

Some examples of events and conditions resulting from the novel coronavirus pandemic and their potential impact on management's assessment on the going concern are outlined below:

- Loss of a major market, key customer(s), revenue, labour shortage
- Significant deterioration in the value of assets used to generate cash flows
- Significant deteriorations in the value of current assets – Inventory
- Delay in the launch of new products or services
- Foreign exchange fluctuations
- Measurements affected by increased uncertainty
- Counterparty credit risk
- The entity's solvency

For instance, if the entity has closed some of its physical stores and that caused a significant deterioration in the values of inventory, there might be significant write-downs and write-offs of inventories. In this regard the management has to consider how business disruption will further affect the entity after the restrictions have eased. As there are significant fluctuations in foreign exchange rates in the current stressed economic environment and some businesses with international transactions might be significantly affected, the board should take them into account, including their impact on any hedging arrangements aimed to reduce uncertainty arising from the Covid-19 pandemic. Sensitivity analysis of exchange rates movements should be also considered. [8]

Although the boards are not required to follow the auditing standards but only to comply with the applicable financial reporting framework, it is advisable for them to refer to them when assessing the adequacy of the provided disclosure on the going concern.

We would like to highlight that circumstances impacting board's assessment of the entity's ability to continue as a going concern might change rapidly in the current evolving environment and that might require assessment decision update. Paragraph 14 of IAS 10 *Events after the Reporting Period* states that any effects of events occurring after the end of the reporting period but before the authorisation of the financial statements for issue need to be reflected if they reveal that management has no other realistic alternative but to cease trading. [11]

4. Disclosure implications in the Covid-19 environment. Good practices.

The specific disclosure requirements relating to going concern, set out in paragraph 25 of IAS 1, should be complemented with the overarching disclosure requirements in the standard and in particular with paragraph 122. The latter requires disclosure of judgements that have significantly affected the amounts recognised in entity's financial statements [5].

If applying the requirements of IAS 1, four scenarios might be outlined, as follows [6]:

- Scenario 1 – there are no significant doubts about the going concern
- Scenario 2 – there are significant doubts about going concern but according to management's judgement going concern is appropriate due to mitigating actions; no material uncertainties are identified
- Scenario 3 – similar to Scenario 2, there are significant doubts about going concern but according to management's judgement going concern is appropriate due to mitigating actions; the difference, if compared to Scenario 2 is that there are material uncertainties about the going concern even after considering mitigating actions
- Scenario 4 – entity's management intends to liquidate or to cease trading, or has no other realistic alternative but to do so

In good times the first scenario is usually followed as there are no complications on board's assessment on the going concern

assumption and related disclosure especially when the company has a history of profitable operations and guaranteed sources for fund raising. In contrast, the short-term disruption to business models makes the going concern assessment a much more complex task. Under both Scenario 2 and Scenario 3 more detailed analyses would be required and additional disclosures should be provided for supporting management's decision that the going concern basis is appropriate. In such cases a variety of factors related to profitability, access to additional funding, debt repayment schemes, etc. should be considered.

Due to the systemic uncertainties caused by the rapid spread of the novel coronavirus, the board might be less confident in stating that the company will be able to meet its obligations and will not cease its operations at least in a 12 months' period. Therefore, company's management is encouraged to provide relevant disclosures around those uncertainties and the impacts created by Covid-19 in medium and longer terms. These disclosures are summarised in table 1.

Table 1 *Disclosures on the going concern assessment in the Covid-19 environment*

• all significant judgements and estimates that were made by the company's management
• how the liquidity risk has been mitigated in the evolving economic environment impacted by the spread of the novel coronavirus
• all breaches or defaults in company's borrowing arrangements during the reporting period
• sources of uncertainty in estimating the carrying amounts of entity's assets and liabilities
• details on capital management – objectives, policies and procedures
• the timing and amount of entity's provisions and contingencies

Source: [9]

The going concern position should be clearly stated as well as the factors that support that decision, such as the cash position, support from others (including government schemes), current business activity etc. The management needs to provide details of the actions (both current and potential future) and their status. Disclosures should be enhanced with any details of the elements of uncertainty (specific to the business) and consideration of the impacts on the business where the position is subject to or impacted by uncertainty. The going concern disclosure should be connected to wider reporting within the report, such as risk and viability disclosures. [4, p. 6]

In particular, in a Covid-19 environment disclosures could be expanded by additionally providing useful forecast and assessments on any further lockdowns and restrictions imposed by the government on the industry, in which the business is operating. In addition, any information on government schemes and support packages as well as any details on the outcome of discussion with the fund providers, incl. banks, will be of investors' benefit. The short term implications on business operations comprise of impacts on customers and suppliers, expenses, prices and revenues, human capital, etc.

Another issue that should be considered is the depth of analyses performed [12] and whether the provided disclosures on the going concern assessment are sufficiently detailed. The issue implies:

- the relevance of disclosed information about the board's decision and the rationale behind it
- factors, uncertainties and contexts that must be understood
- interaction of the going concern disclosure with viability and risk disclosure [4]

In some jurisdictions, there might be implications regarding the period of assessment. For instance, in Australia, New Zealand and the UK, some modifications to the auditing standards have been introduced at a local level. From the management perspective, it implies consideration of no less than 12 months' period from the approval date of the entity's financial statements [10]. Such longer periods are consistent with the requirements in IAS 1, which establishes only the minimum period to be considered [6].

Some practice examples of going concern disclosures in a Covid-19 environment are provided in table 2.

Table 2 *Practice examples of going concern disclosures in the Covid-19 environment*

Company	Where?	What is useful?
Team 17 Group plc	Annual report for year ended 31 December 2019, p. 59	The company highlights that it has considered the impact of Covid-19 by carrying out a sensitivity analysis and as a result confirms that sufficient cash is available to meet its obligations over the relevant period.
G Barr plc	Annual report and accounts for the year ended 25 January 2020. p. 116	The company highlights that Covid-19 has been considered for assessing going concern and medium and longer-term viability. It confirms it has carried out scenario analysis, considering a number of factors. It also states the key assumption (Staying open) and confirms it has sufficient headroom on financing facilities.
Trainline plc	Annual report and financial statement for the year ended 29 February 2020. p. 55,57	The company provides some detail around how Covid-19 has been factored into the forecasts used to underpin its going concern assessment. It also highlights a number of actions. The statement is supported by detail in the audit committee report on oversight over the process.
Premier Oil plc	Annual report and financial statement for the year ended 31 December 2019. p. 55,57	The company details its base case and assumptions, and highlights that it has undertaken some sensitivity analysis. It highlights that Covid-19 has impacted one of its assumptions beyond the sensitivity conducted. It has considered this impact as well as a failure in corporate actions, and believes mitigating action could be taken. In the disclosure, it also considers circumstances where mitigations do not occur or are not effective.

Source: [4], pp. 9-13.

The aforeprovided examples reveal different management approaches in disclosing information about the going concern assessment, relevant to the entity's business and industry, factors of uncertainty and its future prospects in the evolving Covid-19 environment. What they have in common is the undertaken sensitivity analysis for confirming company's sufficient financing and viability under different scenarios and the disclosed mitigating actions. A good practice might be to include detail in the audit committee report on oversight over the process that supports the management statement.

5. Conclusion

Despite the degree of the Covid-19 impact on the business performance and future implication on the going concern, risk and viability, the board should provide sufficient information for the investors to understand which are the key factors that affect the level of uncertainty and the future of the company over the short, medium and longer terms.

Detailed disclosures about coronavirus-related uncertainties in the going concern assessment can help investors and other stakeholders understand different aspect of the company's prospects. However, it is not possible to address all investor questions in the entity's reports. Good comprehension might be gained through high quality, connected and holistic disclosure across the reports, both annual and interim [4].

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CO2 credit reduction rate impact on the economy of the 27MW wind power farm Case study: Qafë-Thanë, Pogradec

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Abstract: *This work is focused on CO2 credit rate impact application as one of the most feasible technology to make the wind turbines cost effective for power generation. Wind energy is clean, infinite and environment friendly source of energy. However, wind energy systems, alone or hybrid systems have a high potential to reduce CO_2 emissions, fuel and total cost of the system compared to the other options applied historically in power sector. Such systems are foreseen to play a key role in a stable, costless and emission-less way especially in large scale applications. The performance, availability, costs and carbon intensity of wind power indicate that CO2 credit rate can make a very substantial contribution to reduce carbon emissions and gain the security of investment of RES technologies. The other options applied would deliver only partial emission reductions, therefore, are not sufficient to attain the 2030 national energy goals so they have to rely on renewable energy technologies. Policy makers and interest parties/investors need to focus unerringly on scaling up the actual developed few options consistent with reaching the zero-emission goal.*
Keywords: *Wind Energy, CO_2, GHG, RETScreen Expert 8.*

Introduction

Existing 2030 climate and energy framework and ambition aims to cut at least 40% in GHG from 1990 levels; at least 32% share for renewable energy and at least 32.5% improvement in energy efficiency. Despite cost declines and continuous policy support, faster wind growth hinges on resolving social acceptance, permitting and grid integration problems [1]. The cost of electricity generation from onshore wind continues to decrease, with the global average falling to $53/MWh in 2019 due to advancements in turbine design, capacity factors are rising, making projects bankable even in areas with low wind speeds. Another significant issue is that between 2012 and 2018, the LCOE of solar PV fell by 77%, CSP by 46%, onshore wind by 35% and offshore wind by 20%. Costs are expected to continue to decline by 25% for solar and wind power technologies to 2030 [2].

This article presents a concrete 27MW wind system located in south-east part of Albania which will contribute to the diversification of energy sector with the main aim to achieve 2030 emission reduction goals by 11.5% in 2030 following the EuropeanGreenDeal [3] to cut greenhouse gas emissions 55% by 2030. This increased level of ambition for the next decade will put the EU on a balanced pathway to climate neutrality by 2050. This article presents a consideration and detailed analysis of 27MW grid-connected wind farm with the aim to extend its capacity in the future. Albania offers a very favorable geographic position for fostering and developing such environmentally friendly energy types for electricity generation. The CO2 emission factor of 278.94 kgCO2/GJ represent the mass of greenhouse gas emitted per unit of energy generated is calculated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of equipment. In the other hand the depletion of fossil fuel and the negative effect on the environment as well as the potential techno-economic merits of "*hybrid combinations*" identified as a good solution moving towards reliable and more feasible energy systems based on renewables [4]. Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions [5].

The cost of manufacturing wind turbines has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form to be replaced and integrated in existing power systems. Wind power plants have a lifespan of roughly 20-25 years so that optional GHG reduction credit, per equivalent tonne of CO_2 (tCO_2) in conjunction with the net GHG reduction can be used to calculate the annual GHG reduction revenue. Prices for GHG reduction credits, per equivalent tonne of CO_2 (tCO_2), vary widely depending on how the credit is generated and how it will be delivered to achieve the most feasible option in RES projects.

1.1 Site background

The facility area is around 22 km square geographically located at (Lat, Long) 41.04110°, 20.59580°. The installation site will be located in Pogradec near the border with North Macedonia., as it is shown in the map in figure 2.

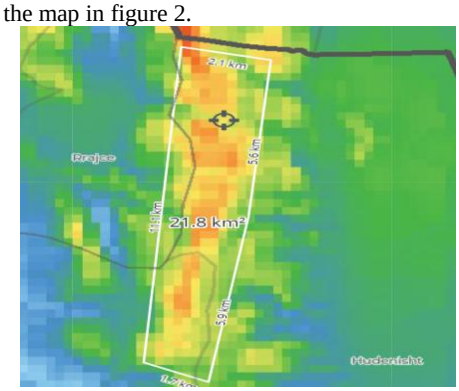


Figure 1: *Wind power plant location. Qafë-Thanë, Pogradec, Albania.*

So, at this point it was achieved to provide power from the wind system including the contribution that such systems can give to support the reduction of GHG into the surrounding environment.

2.0 On - Grid wind systems applications

The economic benefit is assessed based on the LCOE which represents a good starting point to compare benefits and competitiveness of different technologies [6]. Different studies have demonstrated that a WPP system combined with PV offer relatively lower LCOE than traditional fossil fuel based energy plants in Germany [7]

3.0 Materials and Methods

Actually, there are several models available for conducting a set of analysis including environmental impact and benefits. RETScreen Expert is a clean-energy awareness, decision-support and capacity-building tool [8]. This model helps us as energy planers to determine the annual reduction in the emission of greenhouse gases stemming from using the proposed technology in place of the base case technology. The model uses a computerized system with integrated mathematical algorithms and top to bottom approach which has been developed to overcome the barriers to clean energy

technology implementation at the preliminary feasibility stage. It provides a cost analysis, GHG emission reduction analysis, financial summary, sensitivity analysis, provides a low-cost preliminary assessment of RES projects with a small set of a detailed information. Methodology 2 as the more suitable to perform the techno-economical analysis is chosen [9].

4.0 Emission reduction analysis and simulation results

The model performs a GHG emission reduction analysis depending on whether the clean energy system under consideration generates electricity or provides other energy requirements. The only difference lies in transmission and distribution losses, which are incurred only by electricity generating systems and the reduction Δ_{GHG} is calculated. Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T&D losses of the different fuel types. For fuel type selected, diesel 6, 100% single fuel mix, units are given in (kg/GJ) as it is shown in table 1.

Table 2: Emission factors for the chosen fuel type taken in the study (Diesel 6)

Fuel Type (Base case)	Fuel Mix	CO2 emission factor (kg/GJ)	CH4 emission factor (kg/GJ)	N2O emission factor (kg/GJ)	Electricity Generation efficiency (%)	T&D losses (%)	GHG emission factor (tCO2/MWh)
Fuel Mix	100 %	74.12	0.0029	0.0019	28.5	**7**	1.01
Electricity Mix	100 %	278.9	0.0108	0.0072		**7**	1.01

In the baseline scenario the diesel 6 fuel type is. Knowing that a typical Genset could have an electricity generation efficiency of 28.6% and CO_2 emission factor results 278.9kg/GJ. Specific emission factor for N_2O for the selected fuel type result 0.0019kg/GJ and 0.0029kg/GJ of CH_4. The GHG emission factor results 1.01kgCO_2/kWh supposing 7% transmission and distribution losses.

Table 2: Calculation of CO_2, CH_4 and N_2O for the base case system.

		VESTAS					W2E				Sinovel		SIEMENS	WIND TO ENERGY			Siemens	
	Capacity N (MW)	5m	V90-1.8 MW - 105m	V90-2.0 MW - 80m	V90-2.0 MW - 90m	V90-3.0 MW - 105m	V90-3.0 MW - 100m	100/2.5 - 117 - 100m	100/2.5 - 85 - 100m	100/2.5 - 98.7 - 100m	100/2.5 - 141 - 100m	SL3000/100-110	SL1500/82 - 80m	AN BONUS 1 MW 70m	100/2000 - 100m	93/2000 - 100m	120/3000 - 100m	Vensys70 - 85m	Vensys77 - 85m
Sc_6	**27**	0	0	1	0	0	0	0	0	0	0	0	0	0	5	3	3	0	0

From the previous study scenario 6 as the most feasible scenario among 14 taken in analysis is chosen.

The total electricity generation results 61020nMWh/yr and implies two different wind technologies Vestas and Wind to Energy.

Table 3: CO_2, CH_4 and N_2O base case emission factor.

Fuel Type (Baseline GHG Summary)	Fuel Mix	CO2 emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption (TWh)	GHG emission factor	GHG emission (tCO2)
Electricity	100%	278.945	0.0108	0.0072	0.6101	1.01	61759

5.0 GHG reduction credit

In this case study the optional GHG reduction credit rate($25/tCO2), per equivalent tonne of CO_2 is considered. It is used in conjunction with the net GHG reduction to calculate the annual GHG reduction revenue. Prices for GHG reduction credits, per equivalent tonne of CO_2 (tCO_2), vary widely depending on how the credit is generated and how it will be delivered. As of May 2014, prices including rates for carbon taxes varied between $1 to $168 per tonne of CO_2 [10-11]. The model escalates the GHG reduction credit rate yearly according to the GHG reduction credit escalation rate starting from year 1 and throughout the GHG reduction credit duration as it is given in the table 4.

Table 4: GHG reduction revenue and assumptions

	Unit	Value
GHG reduction credit rate	$/tCO2	25
GHG reduction credit duration	yr	25
GHG reduction credit escalation rate	%	2.0

Table 5: GHG reduction revenue and assumptions

	Unit	Value
Gross annual GHG emission reduction	tCO2	57,436.3
GHG credit transaction fee	%	2.0
Net annual GHG emission reduction	tCO2	56,287.6
GHG reduction revenue	$	9,850,329

The percentage of credits that will have to be paid annually at a transaction fee is considered and to obtain credits for a GHG project, a portion of the credits might have to be subtracted at a transaction fee of 2% is assumed to be paid each year to the crediting agency. The model then reduces the gross annual GHG emission reductions by this percentage and calculates the net annual GHG emission reduction of 56,287.6 tCO2 as it is given in table 5:

Table 6: Calculation of the carbon credit revenue

GHG reduction credit rate	$/tCO2	25
GHG reduction credit duration	Yrs	25
GHG reduction credit escalation rate	%	2.0
Gross annual GHG emission reduction	tCO2	57436
GHG credits transaction fee	%	2
Net annual GHG emission reduction	tCO2	56288
GHG reduction revenue	$	1407190

The GHG reduction credit escalation rate of 2%, which is the projected annual average rate of increase in the GHG reduction credit rate over the project life is given in table 6. This allows us to apply rates of inflation to the value of GHG reduction credit rates, which might be different from general inflation (2.5%) taken in the study. Carbon credit instruments often coexist with other heterogeneous policies that may directly or indirectly contribute to reducing GHG emissions by addressing areas such energy or infrastructure. In our study they have to be planned to interact and complement other strategic priorities at local and national levels. The GHG reduction credit duration is accepted to be applied all

into the whole lifetime of the proposed WPP system with a reduction credit escalation rate of 2.0%. The net annual GHG results 56288 tCO2 leading to $1407190 of GHG reduction revenue. The credit transaction fee is accepted 2%. In the graph in figure 3 the results of the simulations of the proposed WPP with a net power capacity 27MW compared to that of the base case (diesel 6) is given.

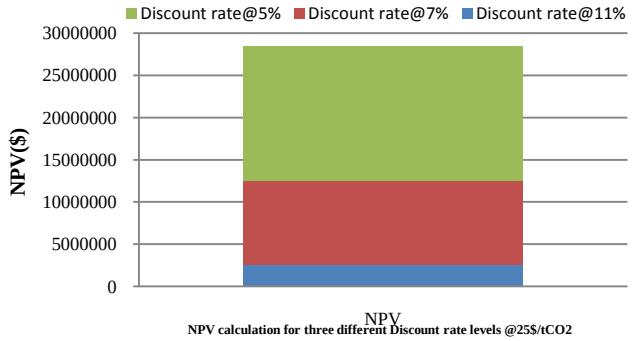


Figure 2: *NPV calculation for three different discount rate levels @25$/tCO2 GHG reduction credit rate.*

In addition, a sensitivity analysis is conducted to test the effects of several key parameters on NPV and cost of energy. In the sensitivity analysis generated from the model, NPV of each option can be calculated by varying the key parameters within a range of ±35%, debt ratio 70%, debt interest rate, debt term and cost of energy for three chosen discount levels 5,7 and 11%. The sensitivity analysis results for each carbon reduction credit rate of $25/tCO2 is summarized in graphs in figure 3.

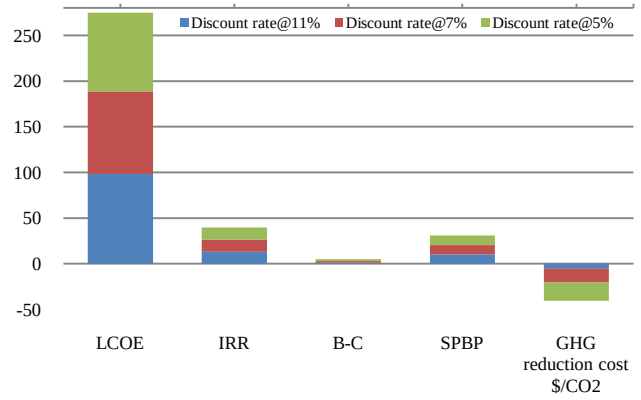


Figure 3: *Results of the simulation for three different discount rates.*

The model calculates the pre-tax internal rate of return (IRR) on equity (%), which represents the true interest yield provided by the project equity over its life before income tax for an inflation rate of 2.5%. The most obvious advantage of using the internal rate of return indicator to evaluate a project is that the outcome does not depend on a discount rate that is specific to a given wind project. Higher the discount rate higher the LCOE results.

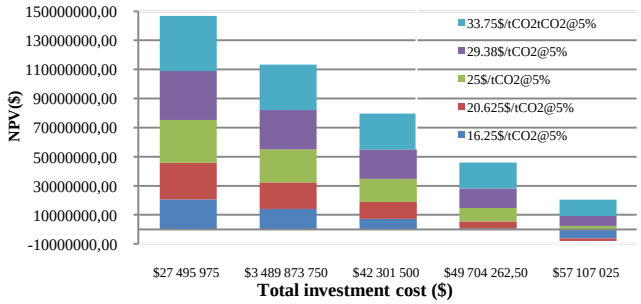


Figure 4: *NPV calculation as a function of total investment cost and GHG reduction credit rate at a sensitivity range of 35% and a discount rate of 5%.*

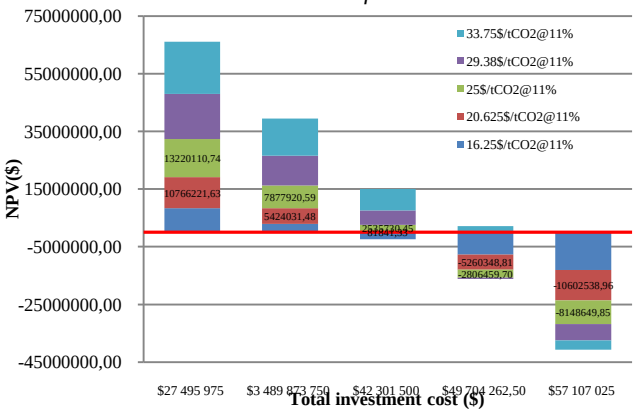


Figure 5: *NPV calculation as a function of total investment cost and GHG reduction credit rate at a sensitivity range of 35% and a discount rate of 11%.*

Changing both total investment cost ($) and GHG reduction rate from 25 to 20 ($/tCO2) it is shown that NPV change at a rate of 22.8% referring the lower total investment cost (-35%) which results ($10766221.6). As a conclusion this project is more profitable if the GHG reduction rate is higher and the total investment cost results 35% less than the fix installation price of m$/1.3MW.

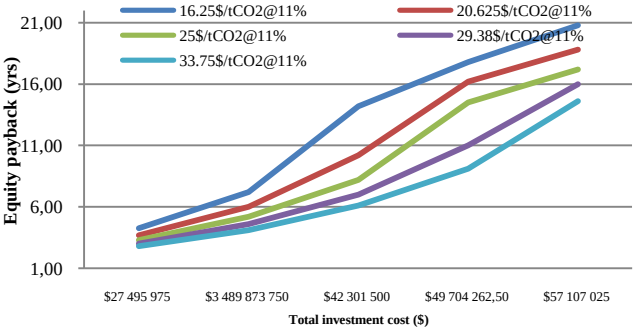


Figure 5: *Equity Payback calculation as a function of total investment cost and GHG reduction credit rate at a sensitivity range of ±35% and a discount rate of 11%.*

The model calculates the equity payback (see graph in figure 5), which represents the length of time that it takes for the owner of a facility to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback considers project cash flows from its inception as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The model uses the year number and the cumulative after-tax cash flows in order to calculate this value. From the simulation it is shown that lower the GHG reduction credit rate and total investment cost, lower the equity payback results.

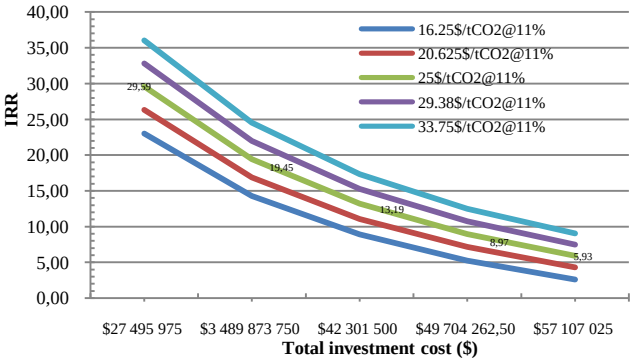


Figure 6: *IRR calculation as a function of total investment cost and GHG reduction credit rate at a sensitivity range of ±35% and a discount rate of 11%.*

The model calculates the pre-tax internal rate of return (IRR) on equity (%), which represents the true interest yield provided by the project equity over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life. From the simulation it is shown that lower the total investment cost ($) higher the IRR results.

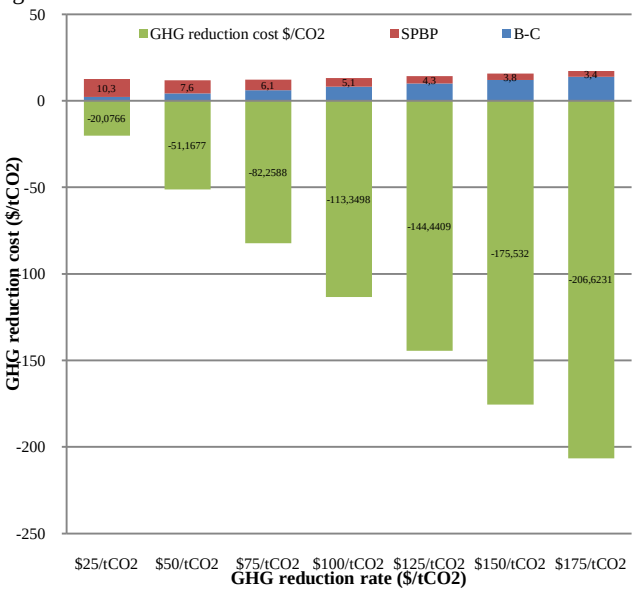
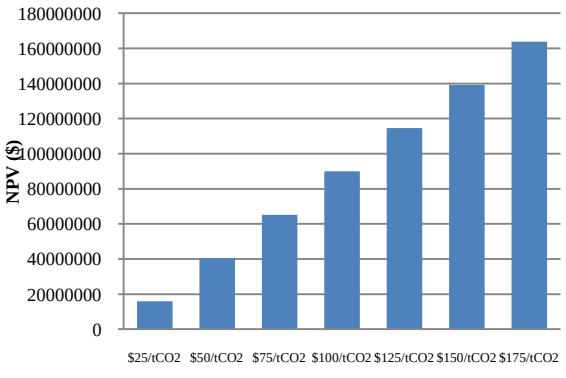


Figure 7: *IRR calculation as a function of total investment cost and GHG reduction credit rate at a sensitivity range of ±35% and a discount rate of 11%.*

The model calculates the GHG reduction cost $/tCO2 as a function of GHG reduction rate $25/tCO2 up to $175/tCO2(see graph in figure 7). The GHG reduction cost is calculated by dividing the annual life cycle savings of the project by the net GHG reduction per year, averaged over the project life for a discount rate of 5%. For facilities with a net increase in GHG emission, the GHG reduction cost is irrelevant and hence not calculated. In order to calculate the true economic (not financial) cost of GHG reductions, a number of other parameters, such as the GHG credits transaction fee, GHG reduction credit rate, debt ratio, IRR,B-C and are considered. The model calculates the simple payback (SPBP), which represents the length of time that it takes for a proposed facility to recoup its own initial cost, out of the revenue or savings it generates. The basic premise of the simple payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment. Changing the GHG reduction rate from $25/tCO2 to $50/tCO2 the SPBP results 35,52% lower, B-C ratio result twice time higher and GHG reduction cost $-51.1677/tCO2 while NPV and GHG reduction cost results 2.5 higher, respectively.



GHG reduction rate ($/tCO2) at a discount rate of 5%

Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with an investment project.

Other factors which have an impact on price may include: voluntary or mandatory emissions reduction; private or public purchase of credits; credits traded within, for example, the European Union Greenhouse Gas Emission Trading Scheme (EU ETS), other national, transnational, or regional schemes; type of technology used to generate the emissions reductions; and others.

As of May 2014, prices (including rates for carbon taxes) varied between $US 1 to $US 168 per tonne of CO2 [World Bank Group/ECOFYS, 2014].

6. Conclusion

The present paper addresses various aspects related to a 27MW on-grid WPP situated in Qafë-Thanë, Pogradec, including an universal understanding of the GHG emission mitigation process. Nowadays, benefits coming from the WPP system is becoming extremely interesting from both, techno-economical and environmental point of view. The wind power diversifies the national energy portfolio being part as a clean, inexhaustible energy resource that doesn't use water. Can be used in a variety of transformation and applications and can be easily integrated with minimal cost increases.

In this paper, the feasibility of 27MW WPP, discussing its potentiality effectiveness by applying a GHG reduction rate of 25$/tCO2 in Albania is analyzed. The impact of such scheme in power sector is very deterministic and should be at the center of energy transition process in Albania. The model calculates the annual GHG reduction revenue which represents the revenue generated by the sale or exchange of the GHG reductions. It is calculated from the annual net GHG reduction and the GHG reduction credit rate. The annual value of GHG reduction revenue is escalated at the GHG reduction credit escalation rate of 2%.

As a conclusion, WPP presents RES technology should be a key center solution in the critical way to deep decarbonization of the power sector in Albania, hence a minimum carbon credits of $25/tCO2 should be applied. The sensitivity analyses performed in various parameters is discussed more deeply in the second part of the related work.

The base system, release 61759.48tCO2 while the wind power scenario can reduce the GHG to 57436.32 tCO2 per year contributing to a better and flexible energy system in our country.

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Innovative self-compacting fiber-reinforced concrete with compensated shrinkage for machinery steel anchors grouting

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Abstract: *The technical design of ETEM factory (Sofia) requires the specialized conveyor stretching machine to be monolithic fitted by using of system of steel anchor rods with a diameter of 30 and 40 mm and different lengths (600-700 mm), which have to be grouted in pre-left holes with a diameter of about 150 mm in steel-reinforced concrete foundation slab.*
The technically determined anchoring depth determines the total thickness of the anchor layer within 700-800 mm, reaching the "lower edge of the steel support plate". The company's produced grouting compositions generally have significant limitations in terms of the maximum allowable thickness of a single layer - usually up to 30-40 mm, which implies multi-stroke implementation to fill the entire anchoring depth.
Given the above, and mainly, taking into account the conditions of laying and the specifics of the operating mode of the facility, the possibility to use concrete batching plant produced high-strength self-compacting fiber-reinforced concrete with compensated shrinkage (to some degree of self-stressing) is estimated as an attractive alternative from a technical and financial point of view.
After the innovative mix design of that an innovative composition of concrete and its casting in real production conditions, specialized laboratory tests were conducted to prove its strength-deformation characteristics - compressive strength, tensile strength in bending, modulus of elastic deformation and shrinkage characteristics. The obtained results prove that the required high technical and technological characteristics of the concrete mix and the hardened concrete are completely achieved precise for the specific application case.
Keywords*: SHOTCRETE, "DRY" AND "WET" SHOTCRETE TECHNOLOGIES, SPECIALIZED CONSTRUCTION REPAIRING WORKS, THIN CONCRETE STRENGTHENING OVERLAYS, INNOVATIVE CONCRETE MIX DESIGN, CONCRETE STRENGTH-DEFORMATION CHARACTERISTICS, X-RAY, DTA, SEM AND BET-METHODS, SPECIALIZED CONSTRUCTION REPAIRING WORKS, THIN CONCRETE STRENGTHENING OVERLAYS*

1. Introduction

The technical design of ETEM factory (Sofia) requires the specialized conveyor stretching machine to be monolithic fitted by using of system of steel anchor rods with a diameter of 30 and 40 mm and different lengths (600-700 mm), which have to be grouted in pre-left holes with a diameter of about 150 mm in steel-reinforced concrete foundation slab - Photo 1 and 2.



Photo 1



Photo 2

Given the above, and mainly, taking into account the conditions of laying and the specifics of the operating mode of the facility, the possibility to use concrete batching plant produced high-strength self-compacting fiber-reinforced concrete with compensated shrinkage (to some degree of self-stressing) is estimated as an attractive alternative from a technical and financial point of view.

After the innovative mix design of that a composition of concrete and its casting in real production conditions, specialized laboratory tests were conducted to prove its strength-deformation characteristics - compressive strength, tensile strength in bending, modulus of elastic deformation and shrinkage characteristics. The obtained results prove that the required high technical and technological characteristics of the concrete mix and the hardened concrete are completely achieved precise for the specific application case.

2. Innovative technical solution

The technically determined anchoring depth determines the total thickness of the anchor layer within 700-800 mm, reaching the "lower edge of the steel support plate". The company's produced grouting compositions generally have significant limitations in terms of the maximum allowable thickness of a single layer - usually up to 30-40 mm, which implies multi-stroke implementation to fill the entire anchoring depth.

The new technical solution proposed is based on the development of a prescribed mix design of self-compacted high-strength shrinkage compensated dispersed-reinforced reinforced concrete (**ShC-SCC**) in accordance of **BDS EN 206:13 +A1:2016** Specification, properties, production and conformity (item 3.1.1.10) and **National Annex (NA):2017**. Taking into account all specific for self-compacted concrete (SCC) additional requirements (**p.4.2.2 Classes for additional properties**) the design compressive strength has to be more than 60 MPa.

For the development of the prescribed mix design, conventional (in the product range of batching plant HYDROBETON OOD, Sofia) and innovative composite materials are proposed, corresponding to the most modern world trends in construction materials science - Table 1, 2 and 3; Fig. 1.

Table 1 *Sieve curve of concrete aggregates*

Materials	**Quantity, kg/m^3**
Portland cement CEM I 52,5 R – Devnya	420
Fly ash – Thermal power plant „Republika“	50
River sand, 0-4 mm, Quarry „HB Mineral“	503
Crushed sand, 0-4 mm, Quarry „HB Mineral	305
Crushed aggregate, 4-11,2 mm, Quarry „HB Mineral“	746
Crushed aggregate, 11,2-22,4 mm, Quarry „HB Mineral	218
HRWRA (PCE type) – **Hyperplast PC 230** (Don Construction Products, Bulgaria)	5,04
Retarding admixture – **Flocrete R50** (Don Construction Products, Bulgaria)	1,05
Shrinkage Compensating Admixture **KEPTONITE** (CONIX TRADE, Bulgaria)	15,00
Micro-PP fibres (monofilament type) **BEL-MIX 12-18** (Belgium)	0,500
Mixing water	164
Water-cement ratio	≈0,38

Practically speaking, the use of concrete with compensated drying shrinkage based on ordinary Portland cement and special shrinkage compensating admixtures is a much more attractive option - simply because the provision of special cements for each case is inconvenience of different types. This is exactly the approach used in the current research aimed at assessing the effectiveness of shrinkage compensating chemical admixture (KEPTONITE) applied in exactly the same concrete mix design

made with the most commonly used different types of cement produced by Bulgarian factories [1,2].

3. Fresh concrete production, transport, site-casting and test sampling

The production of the developed composition of **ShC-SCC** is organized and carried out on the basis in the "Iliyantsi" district of HYDROBETON OOD, in full compliance with the regulatory requirements and monitoring of the technical parameters of the concrete mix., incl. consistency (spreading width over 450 mm) - Photo 3.

The transport to the construction site is performed with concrete trucks according to the standard procedure for ordinary concrete. The unloading was carried out from the chute of the concrete truck to the filling of the buckets with concrete mixture, which was manually delivered to the place of laying (with preliminary execution of the necessary formwork works) and laid without the need for additional compacting procedures (Photos 4 and 5).

After laying the concrete, the exposed surface is tightly wrapped in PE-stretch film to ensure normal hydration of the concrete with moisture retention (Photo 6).

Table 2 *All-in Curve of ShC-SCC*

HIDROBETON

Korngruppe	Gesteinskörnung	0,125	0,25	0,5	1	2	4	8	16	32	63	k-Wert
0-4	River sand	3,0	12,3	41,2	70,7	87,7	98,3	100,0	100,0	100,0	100,0	1,90
0-4	Dolomite	14,6	23,1	36,0	55,1	85,6	98,9	100,0	100,0	100,0	100,0	2,01
4-11,2	Dolomite	0,5	0,5	0,5	0,9	4,6	20,6	71,2	100,0	100,0	100,0	5,02
11-22	Dolomite	0,3	0,3	0,5	0,5	0,6	0,6	8,5	75,4	100,0	100,0	6,14

Korngruppe	Gesteinskörnung	Herstell-/Lieferwerk	Vol.-%	kg/dm³
0-4	River sand	Hydroeco PIM OOD, Chelopechene	30,00	2,59
0-4	Dolomite	HB Minerals, Studena	17,00	2,77
4-11,2	Dolomite	HB Minerals, Studena	41,00	2,81
11-22	Dolomite	HB Minerals, Studena	12,00	2,81

Korngruppe	0,125	0,25	0,5	1,0	2,0	4,0	5,6	8,0	11,2	16,0	22,4	31,5	63,0
0-4	0,9	3,7	12,4	21,2	26,3	29,5	30,0	30,0	30,0	30,0	30,0	30,0	30,0
0-4	2,5	3,9	6,1	9,4	14,6	16,8	17,0	17,0	17,0	17,0	17,0	17,0	17,0
4-11,2	0,2	0,2	0,2	0,4	1,9	8,4	17,3	29,2	40,1	41,0	41,0	41,0	41,0
11-22	0,0	0,0	0,1	0,1	0,1	0,1	0,1	1,0	3,3	9,0	11,6	12,0	12,0
Sieblinie	3,6	7,9	18,7	31,0	42,8	54,8	64,4	77,2	90,4	97,0	99,6	100,0	100,0
k-Wert	3,70												

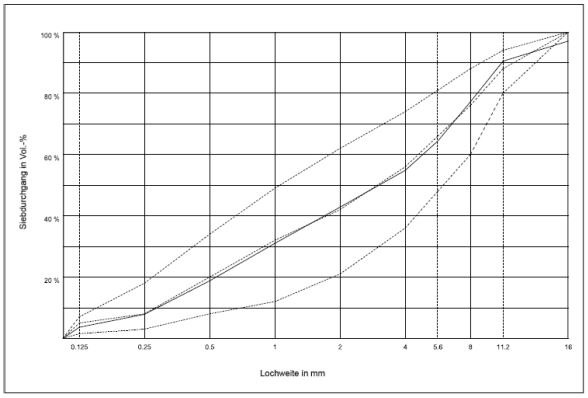


Fig. 1 *All-in Curve of ShC-SCC*



Photo 3



Photo 4

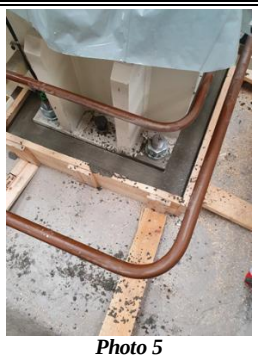


Photo 5

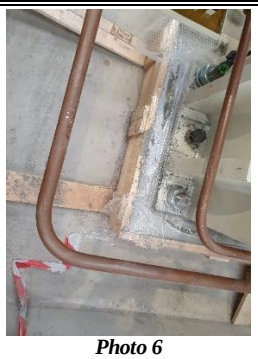


Photo 6

During the concrete casting, the necessary standard test sampling was performed for laboratory establishment of the technical parameters of the hardened concrete of different age in an accredited testing laboratory

4. Lab testing and technical parameters

The planned test procedures were carried out in the UNIVERSITY TESTING LABORATORY (USIL) of the UNIVERSITY OF ARCHITECTURE, CONSTRUCTION AND GEODESY, Sofia. The laboratory is accredited for this type of testing by the Executive Agency "BULGARIAN ACCREDITATION SERVICE" at the Ministry of Economy and has a valid accreditation certificate LI № 239/5.08.2018, valid until 20.08.2022.

The following tests were performed:

4.1. Volume density, compressive and bending tensile strength

The tests are performed in accordance of:

- BDS EN 12390-3:2019 Testing of hardened concrete.
- Part 3: Compressive strength of samples;
- BDS EN 12390-7:2019 Testing of hardened concrete.
- Part 7: Volume density of hardened concrete;
- BDS EN 12390-5:2019 Testing of hardened concrete.
- Part 5: Bending tensile strength of samples (Photos 7-9).

The test results are presented in Table 4.

Table 4 *Volume density, compressive and bending tensile strength*

Characteristic	Value at		
	2 days	7 days	28 days
Volume density, kg/m^3	2410 2400 2415 **Mean: 2410**	2400 2380 2380 **Mean: 2390**	2370 2360 2380 **Mean: 2370**
Meets the requirements for ordinary concrete, according to BDS EN 206: 2013 + A1: 2016 for ordinary concrete from 2000 to 2600 kg/m^3			
Bending tensile strength, MPa	8,8 8,3 8,4 **Mean: 8,50**	10,2 10,8 10,5 **Mean: 10,50**	12,8 11,7 12,2 **Mean: 12,20**
Meets to declared values			
Compressive strength, MPa	49,1 49,4 51,6 **Mean: 50,90**	67,8 65,9 63,4 **Mean: 65,70**	83,4 82,5 81,3 **Mean: 82,40**
Meets the requirements for concrete with compressive strength class C50/60, according to BDS EN 206: 2013 + A1: 2016/NA: 2017, Annex NA.B, for class C50/60, with 2-4 results, minimum - over 57.0 (0.95f_{ck}), average - over 61 (f_{ck} +1)			

4.2. Secant modulus of elastic deformations in compression

Table 5 *Secant modulus of elastic deformations in compression*

Characteristic	Value at 28 days
Secant modulus of elastic deformations in compression, MPa	38,7 40,4 39,8 **Mean: 39,70**
According to BDS EN 1992-1-1: 2005 (Eurocode 2), Table 3.1, for concrete class C50/60 a value of 37 GPa is accepted	

The tests are performed in accordance of BDS EN 12390-13:2013Testing of hardened concrete. Part 13: Determination of secant modulus of elastic deformations in compression (Photo 10). The results are presented in Table 5.

4.3. Shrinkage

The tests are performed in accordance of BDS EN 12390-16:2020 Testing of hardened concrete. Part 16. Shrinkage determination (Photos 11 and 12; Fig. 2).

The results are presented in Table 6.

Table 6 *Concrete shrinkage*

Characteristic	Value at 28 days
Concrete shrinkage, %	0,039 0,039 0,034 **Mean: +0,037 (expanding)**
	Out of norming





Photo 7 and 8 *Bending tests*



Photo 9 *Compression test*



Photo 10 *Modulus*





Photo 11 and 12 *Shrinkage*

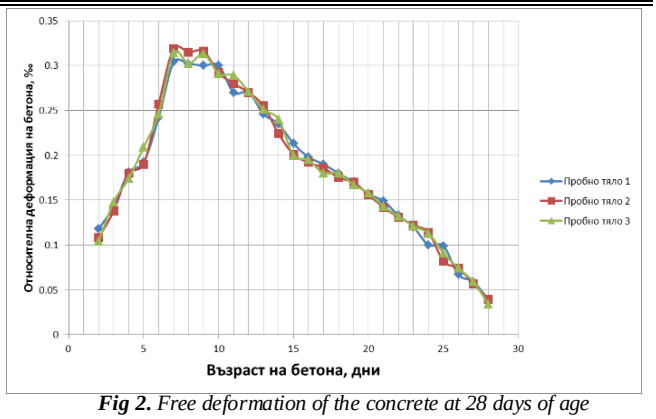


Fig 2. *Free deformation of the concrete at 28 days of age*

5. Conclusion

The test results obtained clearly confirm that the developed and proposed prescribed mix design of self-compacted high-strength shrinkage compensated fiber-reinforced concrete (**ShC-SCC**) in accordance of **BDS EN 206:13 +A1:2016** for grouting of anchor groups of the above subject fully meets of all sets of requirements.

The technical solution proposed provides:

- high technical and technological characteristics of the fresh and hardened concrete, specified for the specific application;
- possibility for factory production of the concrete composition with included special additives;
- manageable delivery quantities, in accordance with the technical possibilities for laying;
- reduced cost of the finished product - price of 1 m^3 of ready-mix concrete delivered to the construction site, up to BGN 200/m^3 (excluding VAT).

References

[1] Valeriy B. Naidenov, Mirona K. Mironova, Opportunities for drying shrinkage minimizing in fiber-reinforced concrete overlays for repairing of corroded industrial structures, Materials, Methods & Technologies ISSN 1314-7269, Volume 14, 2020 (32-40).

[2] Cao Q, Y. Cheng, M. Cao, Q. Gao, "Workability, strength and shrinkage of fiber reinforced expansive self-consolidating concrete", *Construction and Building Materials*, vol. 131, 2017.

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Application of flow-drill technology for joining thin metal materials

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Abstract: *The paper presents the results of testing the joints of unequal materials using flow-drill technology and a combination of flow-drill technology and adhesive bonding. The formed joints were tested by tensile and shear test according to ISO 12996. The positive effect of adhesive bonding on the load-bearing capacity of the joints and on the stress distribution in the tested materials was observed.*
Keywords*: JOINING DISSIMILAR MATERIALS, FLOW-DRILLING, ADHESIVE JOINING, TENSILE TEST*

1. Introduction

The need for a variety of mechanical joining techniques is increasing in the design of lightweight multi-material vehicle structures. The created joints should meet the requirements for safe and rigid joints, but at the same time with sufficient load absorption before failure. Available techniques for mechanical joining, especially of thin-walled profiles, are flow drill screwing, self-piercing riveting and tack setting. The problem with joining thin-walled materials by means of joining elements, in particular screws, is the small number of turns in thin materials, which break immediately under load [1-6]. A suitable solution in this case is the production of holes by flow-drill technology, where heat is generated by friction of the tool, the material softens and instead of conventional drilling by chip removal, a bush with a length three times the material thickness is formed from excess material [7]. This bush is sufficient support for the screw, it can be used to form a thread.

Although this technology is not primarily used to join materials, but only to locally strengthen the cross-section of one material, if we stack two materials on top of each other and let the tool penetrate both materials, under optimal conditions they will be joined by created bushes. The thickness and continuity of the formed bushes, together with the material properties, will determine the resulting mechanical characteristics of the joint [8-15]. If we combine this technology with adhesive bonding, we can eliminate the concentration of stresses around the joint.

The aim of the experimental work was to create and test the load-bearing capacity of joints of thin sheets based on galvanized and non-galvanized steel and aluminum age-hardened alloy, created by flow drill technology in combination with adhesive bonding.

2. Materials and Methods

Three types of materials were used for joints creation:

- uncoated cold rolled extra deep-drawn steel DC04 (hereinafter **DC**) with thickness of 0.8 mm
- hot-dip galvanized high-strength low alloyed steel TL 1550-220 + Z (hereinafter **TL**) with thickness of 0.8 mm
- age-hardened aluminum alloy EN AW-6082 T6 (hereinafter **Al**) with thickness of 1.0 mm

Chemical composition, mechanical properties of materials used are given in Tab. 1.

Tab. 1 *Mechanical properties and chemical composition of materials*

mat.	YS [MPa]	UTS [MPa]	Elong. [%]	Chemical composition [wt.%]
DC	197	327	39	0.04%C, 0.25%Mn, 0.009%P, 0.008%S, Fe-bal.
TL	292	373	34	0.1%C, 1%Mn, 0.5%Si, 0.08%P, 0.03%S, 0.015%Al, 0.1%Nb, 0.15%Ti, 0.2%Cu, Fe-bal.
Al	290	340	15	1%Si, 0.4%Fe, 0.06%Cu, 0.44%Mn, 0.7%Mg, 0.02%Cr, 0.08%Zn, 0.03%Ti, Al-bal.

According to the diameter of the tool (Flowdrill Long ∅ 5.3 mm), the dimensions of the test specimens for the formation of joints were determined on the basis of the ISO 12996 standard and set to 40×110 mm. Joints with a 30 mm bonding line were made from the prepared test specimens and the hole was placed in the middle of the bonding area, Fig. 1.

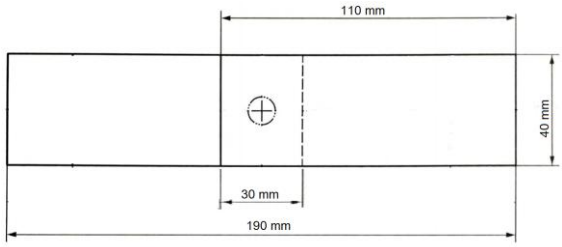


Fig. 1 *Single lap test specimen for combined tensile and shear test*

In the case of joints formed by a combination of adhesive bonding and thermal drilling, a layer of one component, heat curing, solvent free structural rubber adhesive was applied to one of the joined surfaces (Fig. 2), the materials were joined, then a hole was made by thermal drilling and finally the adhesive was cured in an electric oven at 180 °C / 25 min.

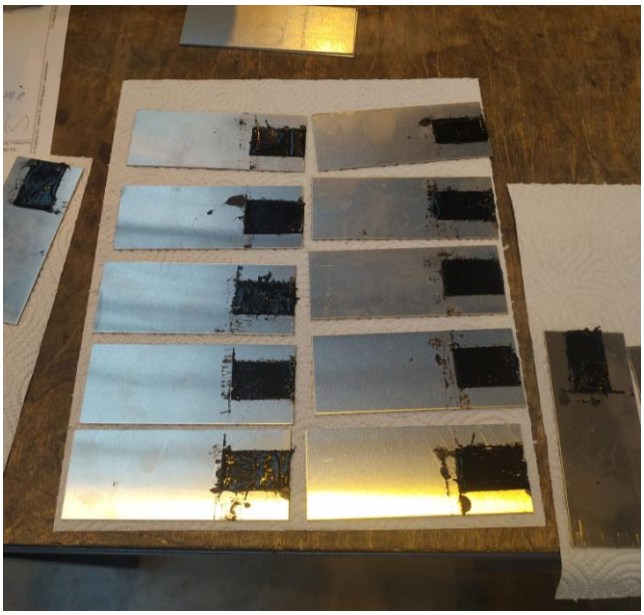


Fig. 2 *Application of adhesive to a defined area*

Joints were made with the following combinations of upper/lower materials: DC/DC, DC/TL, DC/Al, TL/TL, TL/DC, TL/Al, Al/Al, Al/DC, Al/TL. For all joints made of unequal materials, both options (M1/M2 and also M2/M1) have always been tested, as the materials differ in mechanical properties and formability, which can affect bush formation.

The parameters for creating holes by thermal drilling are given in tab. 2.

Tab. 2 *Cutting parameters for holes production*

Peripheral speed	113 m·min^{-1}
Spindle speed	7200 rpm
Feed rate	200 mm·min^{-1} (the movement of the tool ends 0.2 mm below the surface of the top material)
dwell of tool	0.8 sec in the lower position
lubrication	application paste FDKS 100

Joints with a hole, without a thread and without a screw (Fig. 3) were subjected to a tensile shear test on universal testing machine TiraTest 2300. During the test, the maximum force at the joint failure and the load-displacement curve were recorded. The joint loading speed was 10 mm·min^{-1}. After the failure of joints combined with adhesive bonding, the type of joint failure was determined - adhesive, cohesive, mixed.



Fig. 3 *Joint cross-section*

3. Results and discussion

In the production of joints by thermal drilling (without adhesive bonding), it has been shown that some material combinations cannot be joined using the given process parameters. An overview of successfully (OK) / unsuccessfully (NOK) created connections is given in tab. 3. Material combinations where materials have not been successfully joined by thermal drilling have not been further investigated in combination with adhesive bonding, as uncreated or insufficiently formed bushes would not contribute to the strength of the joint combined with adhesive bonding.

Tab. 3 *Overview of successfully/unsuccessfully created joints*

joint		joint		joint	
DC/DC	NOK	TL/TL	NOK	Al/Al	OK
DC/TL	NOK	TL/DC	NOK	Al/DC	OK
DC/Al	NOK	TL/Al	OK	Al/TL	OK

The prerequisite for successfully joining two materials by flow drill technology is that both the top and bottom material will form a continuous bush of sufficient length and both will form a common double bush, with the top material forming the inner layer of the bush, the bottom material the outer layer of the bush. The two bushes together will then contribute to the shear strength of the joint. The reason for the failure of joining some material combinations can be explained by the fact that the top material does not form a sufficiently long bush, or the bush of the bottom material does not have continuous edges but divided by cracks into several segments (petals). The appearance of bushes of joined and unjoined materials is given in Tab. 4.

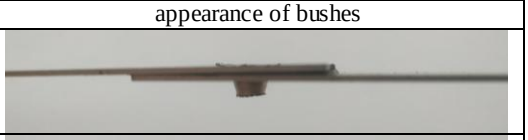
Tab. 4 *Appearance of bushes created by thermal drilling*

joint	appearance of bushes
DC/DC NOK	
DC/TL NOK	
DC/Al NOK	
TL/TL NOK	
TL/DC NOK	
TL/Al OK	
Al/Al OK	
Al/DC OK	
Al/TL OK	

Tab. 4 shows that unjoined pairs showed low or almost no bush of upper material. In one case (DC / Al), both bushes were formed, but the outer bush formed from the bottom material was broken. According to [12], the quality of the bush formed is affected by the spindle speed and the t / d ratio (material thickness / tool diameter). Too high a spindle speed can lead to damage to the integrity of the bush (see DC / Al, TL / Al joints), especially if the bottom material is an aluminum alloy. The lower the t / d ratio, the less material is available to form a bush with a relatively large circumference (relative to the thickness of the material), as a result of which it is more likely to observe cracking and petal formation.

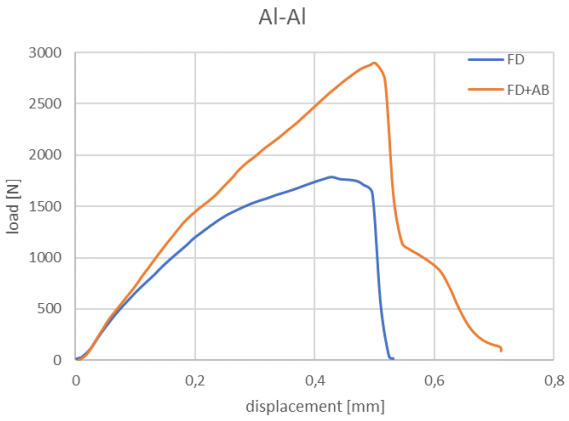
Tab. 5 shows bushes of joints formed by thermal drilling and adhesive bonding.

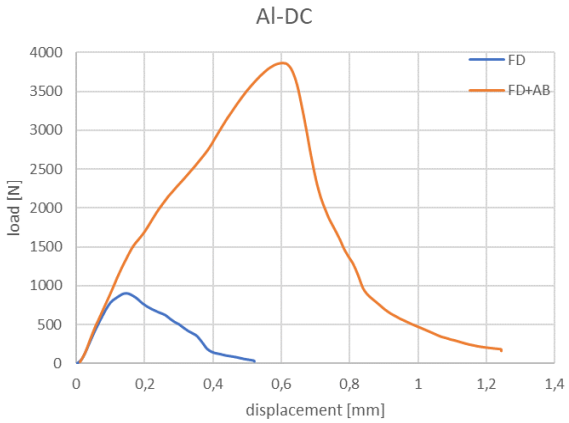
Tab. 5 *Appearance of bushes created by thermal drilling and adhesive bonding*

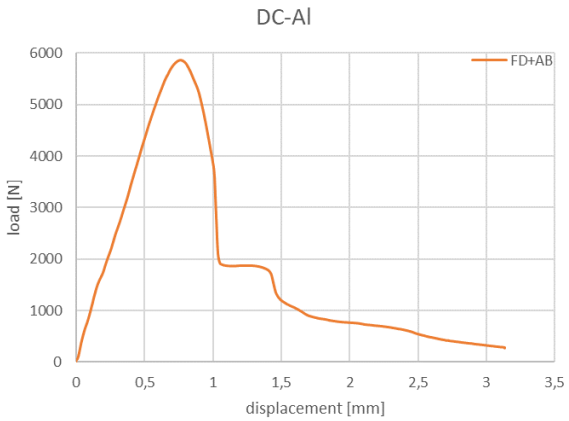
joint	appearance of bushes
Al/Al	
Al/DC	
DC/Al	
Al/TL	
TL/Al	

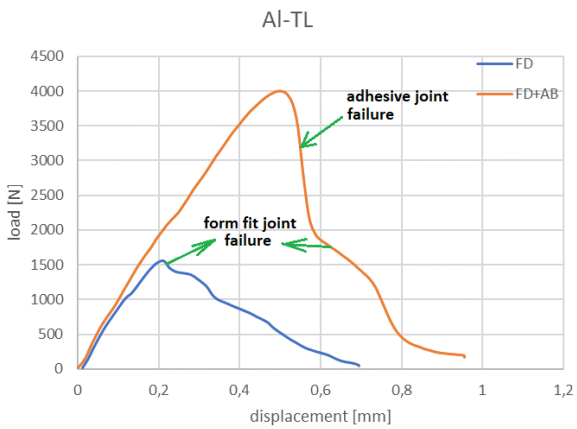
Tab. 5 shows that in joints combined with adhesive bonding, bushes are more integral compared to joints formed without adhesive joining.

Fig. 4 shows the load-displacement curves of the individual material combinations created by the flow-drill and flow-drill technology in combination with the adhesive bonding.









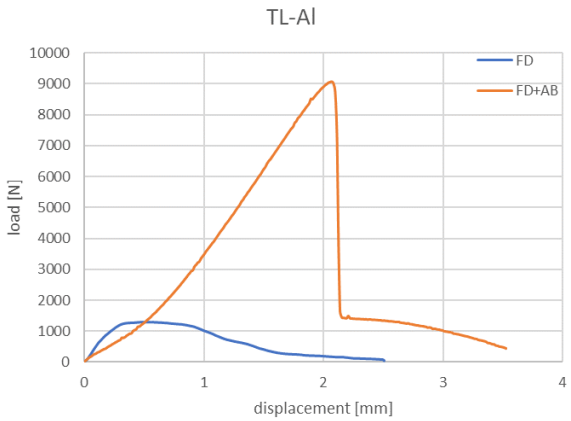


Fig. 4 *Load – displacement curves (FD-flow drill, AB-adhesive bonding)*

The load-displacement curves of the joints formed by the combination of thermal drilling and adhesive bonding reach a maximum after the initial growth, followed by a sharp decrease in the load, which corresponds to a cohesive failure of the adhesive joint. The curve on the descending part generally shows a smaller change in shape at a force which corresponds to the maximum load of the joint created only by thermal drilling, i.e. corresponds to the failure of the bush of the mechanical joint by shearing, Fig. 5. Thus, on load-displacement curves, it is usually possible to distinguish which part of the load-bearing capacity of the joint is provided by the adhesive joint and which part is ensured by the mechanical form fit joint (see Fig. 4 Al/TL load-displacement curve).

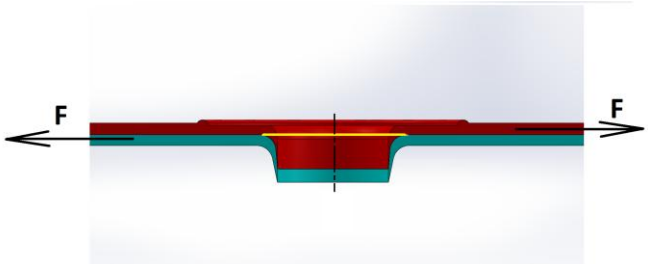


Fig. 5 *Scheme of bush shear failure*

Fig. 6 shows the maximum load at failure of the tested joints.

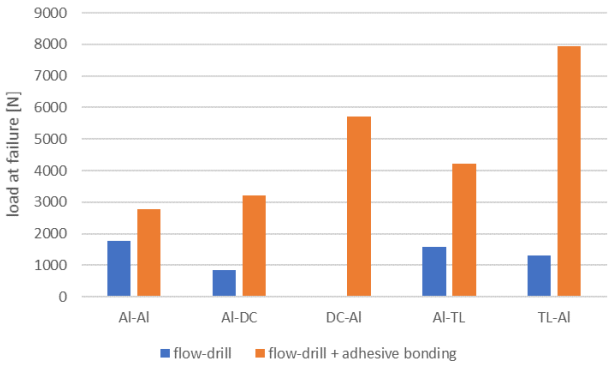
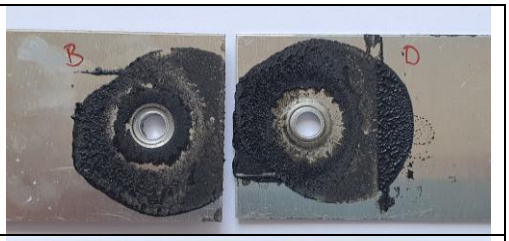
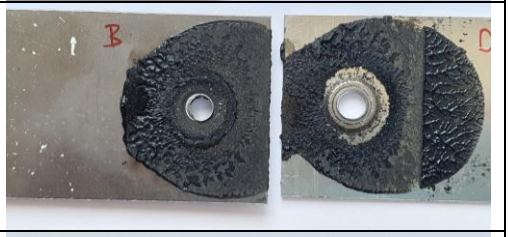
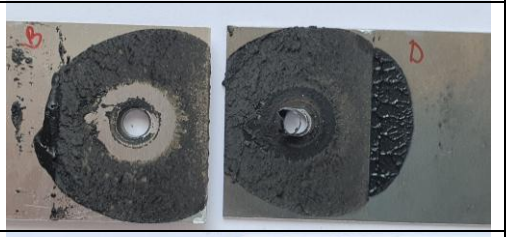
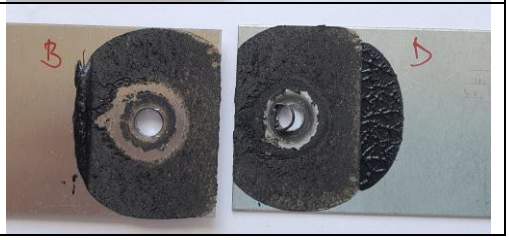


Fig. 6 *Comparison of load-bearing capacity of tested joints*

Fig. 4 shows that adhesive bonding significantly contributes to the strength of the joints in that, in the initial phase of loading, the bonded areas are primarily carrying the load. Only after the adhesive or cohesive failure of the adhesive joint, the bush of the upper material will slow down the final phase of the joint failure process. Tab. 6 shows failure of adhesive-mechanical joints.

Tab. 6 *Appearance of the joint's failure*

Al/Al	
Al/DC	
DC/Al	
Al/TL	
TL/Al	

During the hole formation by thermal drilling, the samples were pressed together, whereby the adhesive applied to the defined surface spread over the circular surface. All joints failed cohesively. There is a narrow intermediate ring around the hole, where the adhesive was adhesively separated from the Al substrate at all joints.

4. Conclusions

The paper presents the results of research into the possibility of joining thin materials by thermal drilling without and with the use of adhesive. Research has shown that all material combinations, where one of the materials is aluminum, either in the upper or lower position in the joint, at given parameters, are suitable for joining. It is also necessary to optimize the thermal drilling parameters because the given parameters led to the formation of a continuous bush in steel materials, while in aluminum cracking and petal formation were observed in the bush. Adhesive bonding has significantly increased the load-bearing capacity of the joints; after the adhesive fails, the final failure of the joint is inhibited by the bush formed from the upper material of the joined material pair.

Recommendations for further research:

- for joining thin sheets, it is possible to recommend increasing the current t/d ratio, which would mean using a smaller drill diameter for the given material thicknesses in order to have a larger supply of material to create a continuous bush.
- Reducing the diameter of the drilling tool would also mean a reduction in the dimensions of the specimens, thus also a reduction in the adhesive-bonded area, which could help to highlight the contribution of the bush cross-section to the bearing capacity of the joint.

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Modern copper electrolyte holes for multi-layer printed curcuit boards

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***Abstract*:** *This work is devoted to the study of the stage of galvanic copper plating of through-holes in multilayer printed circuit boards. Hole plating is one of the most difficult stages and requires high-tech electrolytes and equipment. The present study was carried out within the framework of the development of a domestic electrolyte for copper plating of PCB holes and is devoted to the study of the effect of the nature and concentration of brightening additives on the gloss of a copper coating.*
KEYWORDS: *MULTILAYER PRINTED CIRCUIT BOARDS, GALVANIC COPPER PLATING, COPPER ELECTRODEPOSITION, METALLIZATION OF THROUGH HOLES, CONDUCTIVE LAYER, THROWING POWER, BRIGHTENING ADDITIVES.*

1. Introduction

With the development of technologies, the relevance of creating high-precision printed circuit boards (PCB), which are the main component of electronic devices, increases. The printed circuit board is a dielectric plate (fiberglass, getinax, etc.), on the surface and in the volume of which electrically conductive elements of the electronic circuit are formed, which are intended for the electrical and mechanical connection of electronic components.

Taking into account modern requirements for the dimensions and compactness of products, the most demanded in industry and constituting the bulk of the volume of printed circuit boards produced are multilayer printed circuit boards (MPCB), which are pressed-in alternating layers of dielectric with a conductive pattern (TP) applied. TP are located on the outer sides and inner layers of the dielectric, the electrical connection between which is carried out by metallization of the through holes of the PCB [1].

The main requirements for electroplated copper coating inside the holes and on the surface of the PCB are: continuity and uniformity of the coating, incl. no «dog bone» effect – excessive metal build-up at the inlet of the hole [2]. In addition, the copper plating should be glossy.

2. Preconditions and means for resolving the problem

To prepare solutions of galvanic copper plating, reagents of «pure», «chemically pure» qualifications and distilled water were used. As samples for the deposition of copper coatings, we used plates of foil-clad dielectric (fiberglass) FR-4 with a thickness of 1.5 mm, which is widely used in the production of multilayer printed circuit boards (fig. 1).

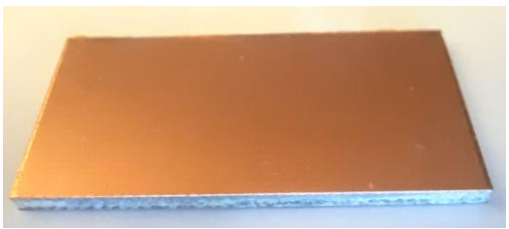


Fig. 1. *Foil-clad dielectric FR-4*

Freshly prepared copper plating electrolyte was worked through to remove impurities for 2 A·h/l (cathode current density is 2 A/dm^2, t = 25^{o}C, mechanical stirring on a magnetic stirrer – 750 rpm).

Before applying a copper coating from the electrolyte under study, FR-4 plates were degreased with Viennese lime and activated in 10-% H_2SO_4. The process of galvanic copper plating of the prepared foil-clad dielectric was carried out under the following conditions: i = 2 A/dm^2, τ = 57 min, t = 25^{o}C, mechanical stirring on a magnetic stirrer – 750 rpm.

One of the main requirements for the quality of the coating is gloss. Therefore, in this work, this characteristic was chosen as a criterion for assessing the quality of the developed electrolyte.

The gloss of the copper plating was measured with a gloss meter «Elcometer 480».

To numerically estimate the gloss value, the GU (Gloss Unit) scale was used. The current standards define the 0 GU and 1000 GU breakpoints (gloss angle 60°). With this value 0 GU corresponds to a matte surface with zero reflection, and the maximum value of GU corresponds to a black glossy surface. The 60° angle is the most universal, therefore, in this work, the gloss was measured at this angle [3]. The gloss measurements of each sample were carried out at least 5 times.

The gloss value of the initial copper foil on the dielectric was 82 GU.

3. Results and discussion

Sulfuric acid electrolytes containing Cu^{2+} and H_2SO_4 in a ratio of 1:10, as well as Cl^- ions, are promising electrolytes for copper plating of PCB holes [4].

Based on the literature data [5-8] and preliminary tests, an electrolyte containing (g/l) was selected as the base one: $CuSO_4 \cdot 5H_2O$ 100, H_2SO_4 (96 %) 200, NaCl 0,11.

The introduction into this electrolyte simultaneously of three types of additives (inhibiting, leveling, brightening) allows to ensure the uniformity and gloss of the coating on the surface of the PCB [4].

The aim of this work was to study the effect of the nature and concentration of brightening additives introduced into the base electrolyte on the gloss of the resulting copper coating.

But before the effect of brightening additives on the gloss of the coating was studied, the gloss of coatings obtained from a base electrolyte (2.3 GU), an electrolyte of the base composition containing imported inhibiting and leveling additives (7.1 GU), as well as an electrolyte from a foreign analogue (636 GU).

The following compounds were considered as brighteners in the concentration range from 0.001 to 0.3 g/l: MPS (sodium salt of 3-mercaptopropane-1-sulfonic acid); UPS (3-(amidinothio)-1-propanesulfonic acid); MSA (methylsulfonic acid); p-TSA (para-toluenesulfonic acid); m-NBS (sodium salt of methanitrobenzenesulfonic acid) (table 1) [9-11].

Table 1: *Dependence of the gloss value of coatings (GU) on the nature and concentration (g/l) of the brightening additive*

[g/l] / Additive	0,001	0,005	0,01	0,05	0,1	0,15	0,3
MPS	4	590	644	5	4	4	4
UPS	4	4	4	5	222	160	121
MSA	8	4	4	4	4	3	3
p-TSA	9	10	14	49	133	151	140
m-NBS	5	5	4	4	3	3	3

Thus, glossy coatings make it possible to obtain an electrolyte containing a brightening MPS additive at a concentration of 0.005-0.01 g/l. The gloss value of the copper coating obtained from the electrolyte of this composition was 590-643 GU, which is comparable to the gloss value of the coating obtained from the electrolyte of a foreign analogue (636 GU).

In the case of UPS and p-TSA additives, a further increase in their concentration in the electrolyte does not lead to an increase in the gloss value of the copper coating. The additions of MSA and m-NBS do not at all contribute to the production of glossy coatings.

4. Conclusion

It has been established that the use of the MPS additive, which is a substance from the class of sulfonic acids, as a brightening additive at its concentration in the electrolyte of 0.005-0.01 g/l, makes it possible to obtain coatings that meet customer-specified gloss requirements.

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Investigation of evaporation with open water surface in forced convection

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Abstract: *Numerous publications in the literature deal with the investigation of evaporation under forced convection; however, no correlation between the available equations would describe the process and the evaporation rate with high reliability and in a wide range of interpretation. The main parameters influencing the evaporation rate are air temperature, relative humidity and velocity of air, liquid temperature, and the surface area of the evaporating liquid. The cases of evaporation were categorized as a function of the indicated parameters under forced convection. For the case with constant gas and liquid parameters, a general Sherwood equation was created using the literature results which can be used to estimate the rate of evaporation, the rate of mass transfer. For this, an equivalent characteristic length and the ratio of gas and liquid temperature were determined.*
Keywords: *SHERWOOD EQUATION, EVAPORATION CATEGORIZATION, EQUIVALENT CHARACTERISTIC LENGTH*

1. Introduction

The phenomenon of evaporation also plays a relevant role in meteorology and technical applications. Evaporation of liquids cannot be neglected, for example, in the cases of cooling towers, reservoirs, swimming pools and spent fuel pools where it is essential to know how much liquid needs to be replaced or released into the atmosphere as a hazardous substance. During simultaneous heat and mass transfer, the evaporation rate is affected by gas and liquid parameters. Gas parameters include gas temperature, gas velocity, humidity and atmospheric pressure. Parameters that characterize the liquid include its type, surface area and temperature.

During evaporation, the gas layer directly above the liquid surface is saturated with liquid-vapor by molecular diffusion, which diffuses into the bulk gas in the absence of gas movement, creating the process of evaporation in natural convection by the buoyancy force from the resulting density difference. If gas movement is also present, the saturated gas layer is entrained by the gas stream, transporting drier gas in place, thus accelerating the rate of evaporation which is called evaporation in forced convection. In mixed convection, the magnitude of the effects resulting from the buoyancy force due to the density difference and the gas velocity is comparable, so both must be considered. The publications on the phenomenon of evaporation in the literature can be grouped according to different aspects: the types of equation giving the evaporation rate [1–3], the measurement procedures [4,5] and the type and direction of the driving forces [6]. However, it is also possible to group evaporation according to physical parameters. By processing the publications in the literature, different evaporation cases can be distinguished with the knowledge of gas and liquid parameters. Figure 1 shows the categories of evaporation at atmospheric pressure in forced convection.

Researchers studying the phenomenon of evaporation are divided on the question of whether the rate of evaporation is affected by the size of the evaporating surface. If the parameters of the gas flowing above the liquid surface can be considered nearly constant along the flow direction, the evaporation rate is not affected by the size of the liquid surface. However, if the gas parameters change significantly along the flow direction, the size of the liquid surface also affects the intensity of evaporation. Thus, three cases can be distinguished for forced convection according to the gas parameters: steady-state, time-varying and along the flow direction varying gas conditions. Cases with steady-state gas conditions mainly involve laboratory measurements where the temperature, humidity and velocity of the flowing gas were kept constant [7–14]. Time-varying gas conditions can occur when the parameters are not controlled, for example, air velocity, humidity or temperature change as a function of time [15–19]. When a larger liquid surface evaporates, such as a reservoir or a lake that can reach hundreds of square kilometers of evaporating surface [20–24], we are already talking about spatially changing gas conditions. Among the liquid parameters, the determinant is the liquid temperature, so that we can speak about steady-state or time-varying liquid temperature. The change in liquid temperature can be modified by heat removal or heat input during evaporation, where a distinction can be made between cases with and without a heat source according to the mode of heat transfer.

After reviewing the literature, it can be said that researchers have studied liquid evaporation since the 1800s, and there is still no exact correlation that could be used to determine the rate of evaporation with high accuracy in a wide range of interpretations. The aim of our research is to create a dimensionless $Sh - Re$ equation for the evaporation category with a steady-state gas and conditions and a steady-state liquid temperature that gives the value of evaporation rate on a broader validity range than before.

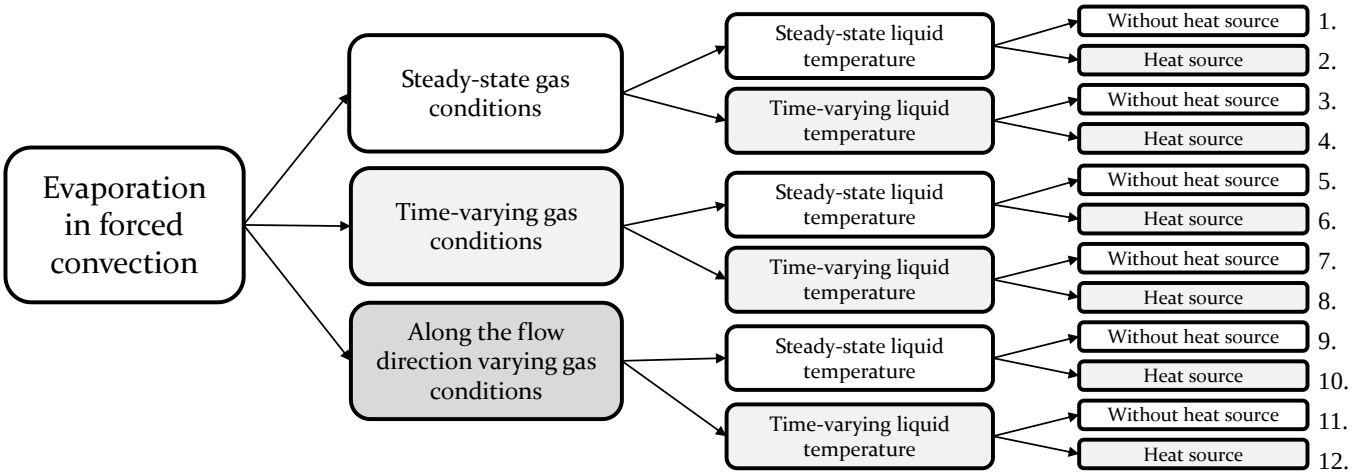


Fig. 1 *The categorization of evaporation as a function of gas and liquid parameters under forced convection*

2. Literature results

In the category of evaporation at steady-state gas conditions and steady-state liquid temperature, the stationary state is assumed. Because in the case without a heat source, the surface temperature of the liquid cools down to the temperature of the wet-bulb temperature at steady-state gas conditions, if the gas velocity reaches a sufficiently high value [25]. If the vessel containing liquid is supplied with a heat source, a constant heat flow provides a constant liquid temperature which leads to a higher temperature than the wet-bulb temperature. In this work, we dealt with these categories of evaporation and the processing of publications that fall into these groups.

The $Sh-Re$ relationship describing the phenomenon was established based on the measurement results found in the literature. Among the publications dealing with evaporation, only those were categorized in which evaporation from a liquid container with an open liquid surface into the gaseous medium took place, and only measurement results determined during actual experiments were reported; no simulation results were used. In these publications, the correlations describing evaporation were mainly established empirically by researchers using regression analysis. These equations depend primarily on the measuring equipment and the measurement technic that were available during the measurement. This is one of the reasons for the many correlations that can be found in the literature. In addition, correlations can only be applied in the circumstances and conditions in which they were established.

In many cases, the publications do not describe the validity ranges of the equations or the data on the measuring device at all or with little information. One of the main shortcomings in publications is the inadequate communication of the measured values or the validity range, or the complete absence of such reporting. This causes the results published in papers to be questioned and/or makes reproducibility impossible.

Thus, during the processing of publications, we used only the measurement results of the articles that reported them in sufficient detail. This means that the article had to include data on gas temperature (t_G), gas velocity (v_G), gas humidity (φ_G), liquid temperature (t_f), evaporating surface size (A) and evaporations rate (N) or the values of other parameters from which they can be determined, such as the partial vapor pressure. Table 1 lists the publications for the first two categories that include sufficient ranges and values for the measurement conditions to the applications. The first category applies to the case of forced convection, steady-state gas conditions, steady-state liquid temperature and without a heat source; the second category is the same as the first, but only for the case with a heat source.

Table 1. *Publications for the first and second evaporation categories with appropriate data for application*

Authors		Year	Evap. Categ.
[7]	Lurie and Michailoff	1936	1.
[9]	Braun and Caplan	1992	
[10]	İnan and Atayilmaz	2017	
[11]	Yen and Landvatter	1970	2.
[26]	Sartori	1988	
[12]	Pauken	1998	
[14]	Raimundo et al	2014	

3. Evaluation method

The $Sh-Re$ equations commonly found in the literature include mainly gas properties with only a tiny amount of liquid properties. Therefore, it is necessary to introduce dimensionless members that also consider the temperature driving force, thus displaying the liquid's surface temperature.

When performing dimensional analysis, in addition to the Re and Sc numbers, the Sherwood equation includes a correction term $\left(\frac{T_G}{T_f}\right)$. That is taking into account the value of the gas and liquid temperatures, which is already an accepted term for heat transfer. Thus, the relationship describing the phenomenon of evaporation is as follows:

$$Sh = ARe^B Sc^C \left(\frac{T_G}{T_f}\right)^D . \#(1)$$

In order to determine this correlation for the two categories examined, the literature publications listed in Table 1 were used as a basis. Most of the dimensionless numbers in Eq. (1) include the size of the characteristic length for the process, which in the case of evaporation is the characteristic length of the evaporating surface. For the evaporation research in each publication, the dimensions and geometries of the vessel that containing the evaporating liquid were different, so the question arises as to whether their comparison is possible on the $Sh-Re$ diagram. Namely, among the literature results that have been processed, the evaporation of vessels filled with liquids of different sizes and shapes has been studied, so interpreting the characteristic size in the created Sherwood equation would become questionable. To avoid this problem and to make the results comparable, it is necessary to introduce an equivalent characteristic length (L_e). In fluid mechanics [27], the concept of hydraulic, or equivalent diameter, has been introduced to determine the friction loss of non-circular pipes. In determining the equivalent diameter, the average wall shear stress and the friction loss are the same. In the case of the evaporation phenomenon, the evaporating surfaces were taken as the same. In the case of a square evaporating surface, the flowing gas must have the same path length everywhere above the liquid surface regardless of the gas flow direction. Namely, the evaporation rate is independent of the plane of the evaporating surface in which the test takes place. Therefore, in the Sherwood equation for evaporation, the characteristic size was taken as an equivalent characteristic length for a non-square liquid surface. Thus, the equivalent characteristic length gives the side length of a square whose evaporating liquid surface is equal to the non-square surface of the same size.

However, after determining the characteristic length, only data series with forced convection were used. Many publications did not distinguish between mixed and forced convection ranges, so data series had to be separated according to the nature of the convection. For this, the Richardson number can be used, which expresses the ratio of the buoyancy term to the flow shear term, i.e., the quotient of the Grashof number for the mass transfer and the squared of the Reynolds number:

$$Ri = \frac{Gr}{Re^2} , \#(2)$$

where dimensionless quantities can be interpreted as follows:

$$Gr = \left|\rho_{G,G} - \rho_{G,f}\right| \frac{\bar{\rho}_G L_e^3 g}{\bar{\mu}_G^2} , \#(3)$$

$$Re = \frac{v_G L_e}{\bar{\nu}_G} . \#(4)$$

If the $\boldsymbol{Ri} < 0.1$ it can be called forced convection, if the $\mathbf{0.1} \leq \boldsymbol{Ri} \leq \mathbf{10}$, it can be named mixed convection and if $\mathbf{10} < Ri$ then it can be talked about natural convection. These limits are used to differentiate the effects of heat transfer, so this was also applied to the case of mass transfer. Data that fell into the mixed convection category were not used in the subsequent steps.

For data sets that fell into the category of forced convection, the Re number can be determined using Eq. (4). The Sc number defined as the ratio of momentum diffusivity and mass diffusivity, and is used to characterize fluid flows in which there are simultaneous momentum and mass diffusion convection processes:

$$Sc = \frac{\bar{\nu}_G}{\bar{D}_G} . \#(5)$$

After determining the Sc number, the calculation of the temperature correction term follows, and finally the Sh number which expresses the ratio of the transfer and conduction component currents:

$$Sh = \frac{k_c L_e}{\bar{D}_G} , \#(6)$$

Table 2. *Literature data for evaporation measurements at steady-state gas conditions, steady-state liquid temperature in forced convection*

Authors		Year	t_f [°C]	v_G [m/s]	t_G [°C]	φ_G [1]	$p_{v,f}$ [kPa]	$p_{v,G}$ [kPa]	Δp_v [kPa]	A [m^2]	Shape	Data [1]	Evap. Categ.
[7]	Lurie and Michailoff	1936	25–70	3.5–8.5	40–200	0.002–0.29	N.D.	N.D.	N.D.	0.0314	circle	28	1.
[9]	Braun and Caplan	1992	7–23	2.5; 5.1	7–38	N.D.	1–2.9	0.6–1.2	N.D.	0.02	square	6	
[11]	Yen and Landvatter	1970	1–30	0.2–1.65	-14–41	N.D.	0.63–4.3	0.08–2.8	N.D.	0.015	rectangle	36	2.
[26]	Sartori	1988	10–35	2.5–5	6–33	0.45; 0.85	N.D.	N.D.	N.D.	1	N.D.	48	

*N.D. means 'No data'.

where the mass transfer coefficient is equal to the mass transfer coefficient as interpreted by the molar concentrations. In the case of evaporation, unimolar diffusion occurs in a two-component system where only one component diffuses through the other, non-diffusible inert component. The role of the diffusing component is liquid-vapor while the inert component is gas, mostly air. At unimolar diffusion, if the concentration is given by molar concentration, the molar current density is as follows:

$$N_c = k_c\left(c_{v,f} - c_{v,G}\right). \#(7)$$

Molar concentrations can be given using the ideal gas law, i.e., the partial pressure of liquid vapor, the universal gas constant and the gas temperature at a given point. Since Eq. (7) has a molar current density while most publications have a mass current density, the molar mass creates a relationship between the two. Thus, the mass transfer coefficient can be determined by the following equation:

$$N = 1000 k_C M_L \left(\frac{p_{v,f}}{RT_f} - \frac{p_{v,G}}{RT_G}\right). \#(8)$$

For the material properties used in the calculation, the second character of the subscript, if any, indicates the temperature at which the parameter should be calculated. In contrast, the average values of material properties indicate the average values calculated for the liquid surface and bulk gas temperature.

4. Discussion and results

Literature data were used to establish the $Sh - Re$ relationship for evaporation of liquids, from which the Ri number was used to determine the data series that fell into categories 1 and 2 of forced convection during evaporation. Table 2 shows the final range of the data series for the publications from Table 1 for evaporation in forced convection. In addition, it also indicates how many data sets from a given publication can be used for evaluation. The data series describes the evaporation of water into the air, so the evaporation of other volatile liquids was not the research subject.

After calculating the required dimensionless numbers, the built-in Solver program of Microsoft Excel was used to determine the coefficients and exponents in the Sherwood equation. The aim of the solution was to minimize the sum of the squared deviation between the calculated Sh number from the existing data and the determined $Sh - Re$ equation. An evolutionary calculation method was used for this solution which using a genetic algorithm.

Figure 2 shows the Sherwood equation generated by the software for the two evaporation categories, and in Table 3 can be seen the correlations themselves and the validity ranges for each parameter. Figure 2/a shows the case without a heat source where a curve is fitted to the measurement data of the two mentioned publications. The absolute value of the largest relative error between the measured and the calculated Sh number from the established correlation was 54%, the average value for the measurement results was 16.3%. Figure 2/b shows the results of the calculation performed for the case of evaporation with a heat source, for which two publications, a total of 84 measurement data sets, were used. The absolute value of the largest relative error was 52% between the measured and calculated Sh number, while the average value was 7.3%. In this case, the measurement points cover an extensive Re number range, up to 1,300 to 351,500. However, there is a larger section in the range where there are no measurement results, between 20,000 and 200,000. Thus, at this stage, the results obtained using the established correlation are uncertain in this range; more measurement results would be needed to confirm the correctness of the correlation. Table 3 lists the validity ranges for each parameter, including Re number, temperature, humidity and velocity of air, water vapor partial pressure in air, liquid temperature and evaporating surface area.

5. Conclusion

The phenomenon of evaporation has occupied researchers since the 1800s, and numerous publications and research have appeared on the subject. Publications on the evaporation of open-surface liquids have been collected from the literature. It was found that the evaporation process is influenced by gas and liquid parameters: gas temperature, humidity and velocity of gas, temperature and type of liquid and the size of the liquid surface. According to these parameters, the evaporation process was categorized, so it can be distinguished evaporation under natural, mixed and forced convection according to the nature of the gas flow. In the course of our work, we dealt with the latter category, where within the category of evaporation in forced convection, it can be spoken the case of steady-state, time-varying or along flow direction varying gas condition. According to the liquid parameters, it can be distinguished steady-state and time-varying liquid temperature, including liquid without or with a heat source.

For the first two categories of forced convection, publications dealt with evaporation were collected and then the articles that published the measurement results with adequate data were selected.

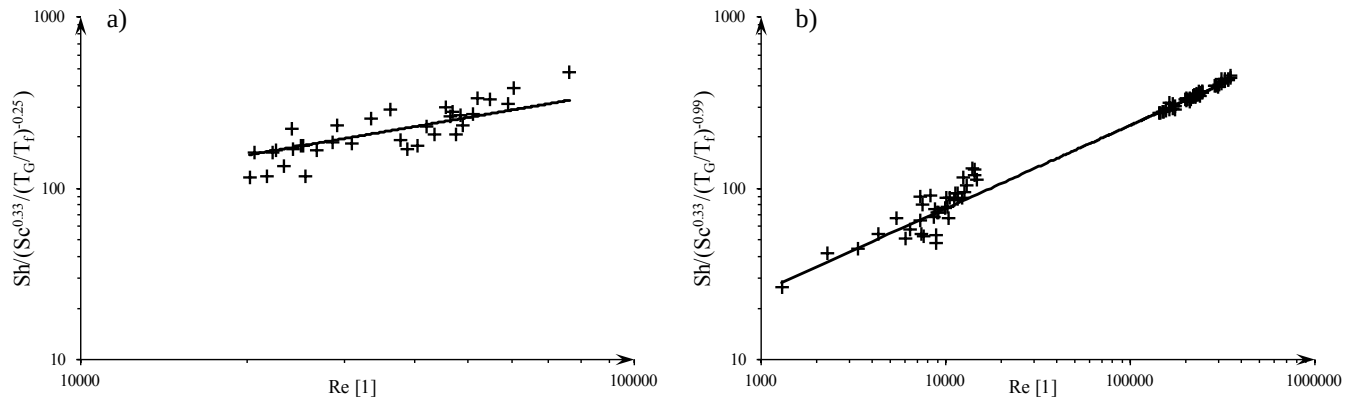


Fig. 2 *The Sh number in the function of Re number a) for the first category b) for the second category*

Table 3. *Equations for evaporation rate at steady-state gas conditions, steady-state liquid temperature in forced convection*

Evap. Categ.	Equation	Re [1]	t_f [°C]	v_G [m/s]	t_G [°C]	φ_G [1]	$p_{v,f}$ [kPa]	$p_{v,G}$ [kPa]	Δp_v [kPa]	A [m^2]
1.	$Sh = 0.68 Re^{0.55} Sc^{0.33} \left(\frac{T_G}{T_f}\right)^{-0.25}$	20 200–76 000	7–70	2.5–8.5	7–200	0.002–0.78	1–30.5	0.6–22.3	0.3–10.4	0.02–0.03
2.	$Sh = 0.87 Re^{0.49} Sc^{0.33} \left(\frac{T_G}{T_f}\right)^{-0.99}$	1 300–351 500	1–35	0.2–5	-14–41	0.12-1	0.6–5.6	0.07–4.2	0.3–3.6	0.015–1

From the measurement results, evaporation measurements in forced convection were grouped based on the Ri number. Then a $Sh - Re$ equation was created for the first two categories based on the data series. In the equation of dimensionless quantities, the equivalent characteristic length is introduced, which is the side length of the square evaporating liquid surface that equal to the size of the non-square liquid surface. In addition, a temperature correction term has been added to take into account the driving force resulting from the temperature difference. The equation created for the first category is valid in the range of $20\,200 \leq Re \leq 76\,000$, and the absolute value of the average relative error is 16.3% for the measured and calculated results. The equation created for the second category is valid in the range of $1\,300 \leq Re \leq 351\,500$, and the absolute value of the average relative error is 7.3% for the measured and calculated results.

Nomenclature

A	evaporating surface [m^2]
c	molar concentration [mol/m^3]
D	diffusion coefficient [m/s]
g	gravitational acceleration [m/s^2]
Gr	Grashof number [1]
k_c	mass transfer coefficient with molar concentration [m/s]
L_e	equivalent characteristic length [m]
M_L	molar mass of liquid [g/mol]
N	evaporation rate [$kg/m^2/s$]
N_c	evaporation rate [$mol/m^2/s$]
p	partial pressure [Pa]
R	ideal gas constant [J/mol/K)]
Re	Reynolds number [1]
Ri	Richardson number [1]
Sh	Sherwood number [1]
Sc	Schmidt number [1]
t	temperature [°C]
T	temperature [K]
v	velocity [m/s]

Greek Letters

ρ	density [kg/m^3]
μ	dynamic viscosity [Pas]
ν	kinematic viscosity [m^2/s]
φ	relative humidity [1]

Subscripts and Superscripts

f	water surface or water surface temperature
G	bulk air or bulk air temperature
v	water vapor

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Preparation of $Ba_{0.95}$ $Sm_{0.05}$ TiO_3 Ceramics by Low Temperature Sol-Gel Method. Change in Dielectric Permittivity with Temperature

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Abstract: *Barium titanate ceramics doped with samarium were synthesized by low temperature sol-gel method. The physicochemical characterization of the samples was carried out by X-ray diffraction (XRD) analysis and scanning electron microscopy (SEM). A pure $BaTiO_3$ cubic phase was obtained. A technological regulation has been developed for the preparation of test samples .Monitoring ofthe relative dielectric permittivity of Sm-doped $BaTiO_3$ ceramics with temperature changes (at frequency of 10 kHz) was realized.The resulting curve is typical of ferromagnetic material. The synthesized barium titanate ceramics possesses a high dielectric constant - 17500 at a Curie temperature Tc (65^oC). The obtained values for the relative dielectric permittivity and Curie temperature of Sm-doped barium titanate ceramics are much better in comparison to conventionally non-doped $BaTiO_3$-ε_r = 2000 and Tc = 120°C.*
Key words: *$BaTiO_3$, CERAMIC, PIEZOMATERIALS, CAPACITORS, PERMITTIVITY*

1. Introduction

The main directions in the development of modern materials science are the development of new products and the optimization of the properties of classical and standard materials with wide application in various technical fields. As a typical example in this aspect can be considered barium titanate, which is characterized by perovskite type crystal structure and the presence of ferroelectric properties [1-3].When the temperature conditions change, successive phase transitions of the first kind take place and formation of different phase structures: cubic (above 120°C), tetragonal (5–120°C), orthorhombic (90–5°C) and rhombohedral (below - 90°C). The structure of the individual modifications can be determinedby application the system of space groups: Pm3m (cubic phase), P4mm (tetragonal phase), Amm2 (orthorhombic phase) and R3m (rhombohedral phase). With a change in temperature values, the dielectric permittivity changes abruptly, and above Tc = 120^{o}C it follows the Curie-Weiss law.The cubic phase is composed of TiO_6 structural polyhedra forming a cube with separate O vertices of and Ti-O-Ti, edges where Ba^{2+} is located in the center of the cube lattice and is characterized by a coordination number 12. Above 1430°C the existence of stable hexagonal modificationof bariumtitanatebelonging to the P63/mmc space group is established.

Different technological methods (conventional high-temperature synthesis, hydrothermal method, peroxide method, etc.) have been developed for the synthesis of $BaTiO_3$ [1,4], which application has a different effect on the structure, micromorphology and properties of the final products. According to the applied technology and the specific reaction conditions (mode of thermal treatment and other factors) it is possible to obtain fine micro-heterograined microstructure, the formation of spherical particles and aggregates with sizes ranging from a few to hundreds nanometers or the formation of a specific dendritic structure, etc.[1,5-7].

The use of high-temperature sintering [1,4] of barium carbonate and titanium dioxide with a thermal treatment in the range 1100^{o}C - 1500^{o}C) is considered as a classical method for the production of barium titanate. The properties of sintered ceramic materials are influenced by a number of factors:type and ratio of raw materials, rate of increase and decrease of temperature, maximum reaction temperature, isothermal retention, gaseous medium in the reaction system, formation of solid solutions, abnormal grain growth,formation of inhomogeneous microstructure, formation of secondary phases in a certain temperature range and others[1].

As a dielectric, barium titanate finds considerable application in the production of single-layer flat-capacitors (plates or disks) or a variety of multilayer ceramic capacitors (MLCCs) [1,8-11]. The dielectric permittivity values up to 7000 have been registered concerning various barium titanate [10], and in a narrow temperature the dielectric permittivity reach to 15,000. The various capacitors with ceramic dielectric possess good temperature resistance, chemical stability, mechanical resistance, ensuring the integrity and durability of the product and are characterized by a wide range of capacitance values. In the production of ceramic capacitors and other articles, barium titanate is applicable as a single phase product or in combination with other phases in systems:$BaTiO_3$-$CaTiO_3$, $BaTiO_3$-$BaSnO_3$, $BaTiO_3$-$CaSnO_3$, $BaTiO_3$-$BaZrO_3$, $BaTiO_3$-$CaZrO_3$ and others[11]. Most of the technical materials are obtained on the basis of binary or more complex solid solutions or mechanical mixtures of compounds with various values of electrophysical parameters. Another important direction for the application of BaTiO3production is:piezoceramic emitters, piezoelectric sensors, microphones, transducers, thermistors, actuators, resonators, posistors, sonar devices, sensors and others[1,8,12-16]. Products based on barium titanium retain their essential importance for modern instrumentation, both due to the presence of appropriate electrophysical and physicochemical properties, as well as the existing tendency to avoid the use ofelectronic components containing lead [8].

Basic technological approaches for variation the characteristics of standard ceramic materials are the change of the technological mode of preparation of the materials and/or introductionappropriate modifiers in the compositions [1]. A number of authors analyze the relationship between the characteristics of modifiers introduced in the compositions, their quantities and the registered changes in the structure and properties of the synthesized phases [.1, 12,14,15].The changes of the electrophysical parameters of ceramic materials during the introduction of different donor ions were studied: Ag^+, Ba^{2+}, Bi^{3+}, Ca^{2+}, Cd^{2+}, Li^+, K^+, La^{3+}, Mg^{2+}, Mn^{4+}, Ge^{4+}, Nb^{5+}, Sb^{3+}, Sb^{5+}, Sr^{2+}, Ti^{2+}, Ta^{5+}, V^{5+} and others[15]. Theapplication of this approach allows through insignificant changes of the initial compositions to preserve the specific properties of the materials and at the same time the implementation of target changes of certain indicators.Therefore, as an effective and promising approach to achieve a favorable change in the electrophysical properties of barium titanium phases and other materials by introducing into the structure of ions with appropriate characteristics (ionic radius, ionic charge and othersAnnex [17-31].

When introducing rare earth ions with a radius in the interval between Ba^{2+} (1, 35 Å) and Ti^{4+} (0, 68 Å), the ions with higher values of the ionic radius (for example La^{3+} - 1, 15 Å or Nd^{3+} - 1, 08 Å) tend to occupy the structural positions of Ba^{2+} (A-site), while the incorporated ions with smaller values of the ionic radius (eg Yb^{3+} - 0.87 Å) are selectively replace Ti^{4+} (B-site). At the same time, the ions with intermediate values of the ionic radius between Ba2 + and Ti4 + (for example Y^{3+} - 0.93 Å, Er^{3+} - 0.96 Å and others) are able to occupy both structural positions of Ba^{2+} or Ti^{4+} (A- and B-sites) in the crystal lattice. [21,25,27]. The value of the Ba/ Ti ratio is an important criterion determining the possible positions of the introduced rare earth ions in the structure. In the presence of Ba / Ti<1, it is assumed that the rare earth ions are localized at the positions of Ba2 +, while in the excessof Ba they occupy structural positions characteristic of $Ti^{4+.}$

It is of significant interest to develope innovative materials based on barium titanate and other phases with optimized complex indicators, applicable in various fields of practice.At the same time, the development and application of ecological and cost-effective

technologies for the production of competitive and durable products at a lower energy consumption compared to conventional high-temperature technologies is of major importance. In this aspect, the sol-gel method offers some significant advantages [32,33] available precursors, application of basic laboratory equipment, work in a standard environment, effective ability to control the reaction conditions of synthesis, obtaining a variety of products with specified properties, application of heat treatment at relatively low temperatures and others.

The aim of the present work is to obtain samarium-doped barium titanate ceramics distinguish by high dielectric pemittivity. The synthesis of the material is realized by low temperature sol-gel method. The change of the relative dielectric permittivity of the obtained barium titanate ceramics with the temperature is monitored and a comparison with data for undoped $BaTiO_3$ is carried out. Based on the analyzed experimental results and the developed laboratory methodologya technological regulation for the preparation of test specimens has been worked out.[34, 35]

2. Results and Discussion

Samarium doped ceramics $Ba_{0.95}Sm_{0.05}$ TiO_3 was characterized by X-ray phase analysis (XRD). Bruker D8 advance automatic X-ray diffractometer with Cu Kα radiation (Ni filter) Lynx Eye solid detector was used. The X-ray spectrum is recorded in the range 10-80 2θ.

The scaning electron microscopy (SEM) was implemented by Scanning electron microscope (SEM) "HIROX SH-5500P" with an integrated Energy-Dispersive X-Ray Spectroscopy (EDS) system "QUANTAX 100 Advanced" –Bruker

The pellets for measuring of relative dielectric permittivity are prepared according the next technology: Mixing with 10 percent polyvinyl alcohol and pressing in metal molding equipment. Such obtained samples are placed in ceramic matrix containing α-Al_2O_3 backfill. Thermal treatment of the prepared samples at 1000°C is realized in order to burn the organic compounds and biscuit the material. The final sintering is carried out at 1270°C in order to obtain better strength of the tablet as well as to enhance its density. After cooling suitable treatment is fulfilled. The aim of this processing is to prepare the tablet in suitable shape for monitoring the changes of relative dielectric permittivity with temperature.

Figure 1 presents a X-ray rentgenogram (XRD) of the synthesized Sm doped barium titanium ceramics.

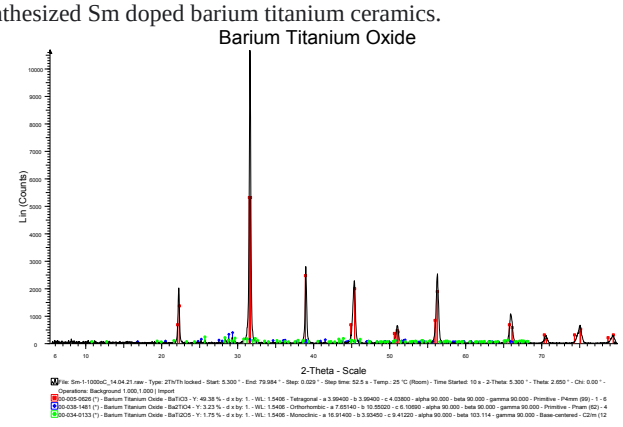


Fig.1 *XRD of cubic Sm doped $BaTiO_3$ phase prepared at 1000°C thermal treatment*

$Ba_{0.95}Sm_{0.05}$ TiO_3 According to the data from the analysis, mainly a cubic phase of $BaTiO_3$ with a small amount of $BaTi_2O_5$ and Ba_2TiO_4 was obtained. The synthesized ceramics is characterized by 2θ peaks at 22.3°; 31.6°; 39°; 45.2°; 51°; 56.1°; 66°; 70.5°; 75°.

Results of SEM-EDS investigation of a sample of $BaTiO_3$ + Sm

Low magnification image (100 x) in SE mode (secondary electrons) showing a general view of the sample. An EDS analysis of the entire area is implemented. The result is presented below the photo of fig. 2.

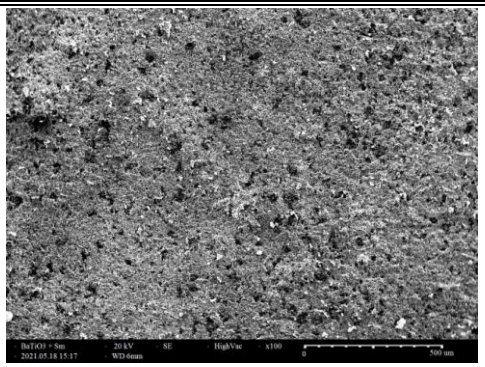


Fig. 2 *SEM analysis of the sample of $BaTiO_3$ + Sm in Low magnification image (100 x)*

1890

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Ba	56	4459	32.73	62.58	30.31	1.08	3.31
Ti	22	2797	15.15	28.96	40.24	0.56	3.68
O	8	140	3.62	6.92	28.77	1.61	44.54
Sm	62	84	0.81	1.54	0.68	0.12	14.84
		Sum	**52.31**	**100.00**	**100.00**		

Second low magnification image (100 x) in SE mode (secondary electrons) showing a general view of the sample. An EDS analysis of the entire area is realized and can be seen in the photo. The result is presented below the fig. 3.

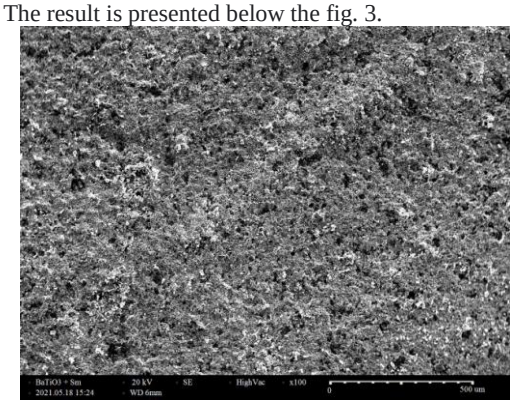


Fig. 3 *SEM analysis of the sample of $BaTiO_3$ + Sm in Low magnification image (100 x).*

1892

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Ba	56	2845	25.68	63.22	29.55	0.92	3.57
Ti	22	1594	10.60	26.11	35.01	0.45	4.20
O	8	118	3.50	8.61	34.56	1.67	47.61
Sm	62	69	0.83	2.05	0.88	0.13	15.82
		Sum	**40.61**	**100.00**	**100.00**		

The data from the EDS analysis indicate the presence of 3.08 mass norm percent for Sm and are in good agreement with the calculated and realized in synthesis of the barium titanate ceramics 3.215 mass percentage.

A higher magnification image (300 x) shows in detail the microstructure of the sample.

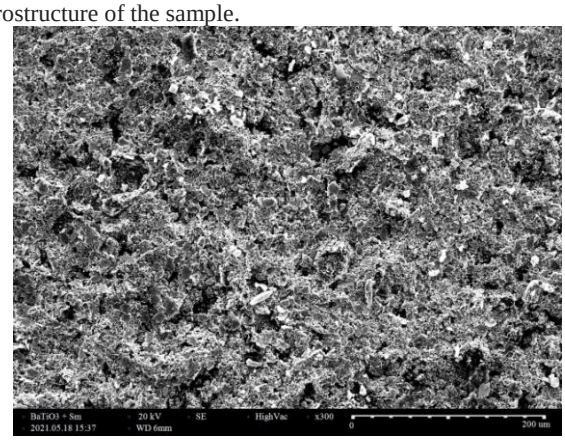


Fig. 4 *SEM analysis of the sample of $BaTiO_3$ + Sm in Low magnification image (300 x).*

Higher magnification image (800 x) showing the microstructure of the sample in more detail.

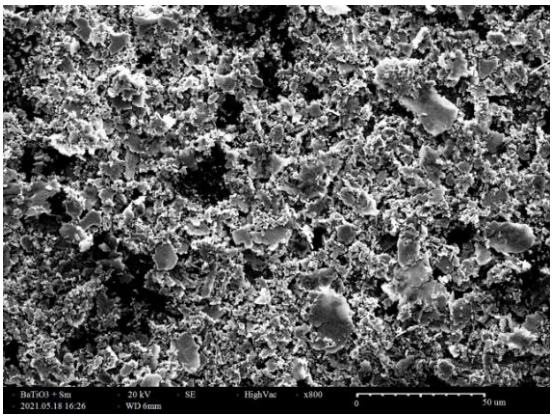


Fig. 5 *SEM analysis of the sample of $BaTiO_3$ + Sm in Low magnification image (800 x).*

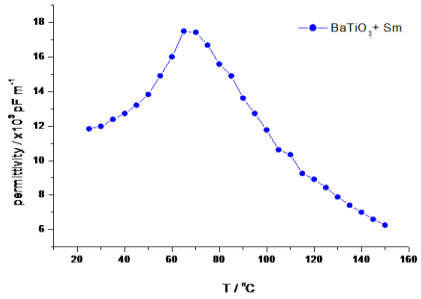


Fig. 6 *Relationship between the RDP and measured temperature.*

In Fig.6 the change of the relative dielectric permittivity with increasing temperature is presented. The measurements are realized at frequency 10 KHz.

It is noteworthy that the obtained curve is typical for ferroelectric ceramics and is characterized by a maximum at 17.50259 at a Curie temperature (Tc = 65°C) according to the attached table. It can be seen that the temperature of the ferroelectric - paraelectric (Tc) phase transition of the synthesized ceramics is significantly lower than the undoped $BaTiO_3$ (120°C).

Table 3. *The relative dielectric permittivity value related to the measured temperature*

°C	Permittivity x10^3 [pF/m]
25	11,85
40	12,73534
50	13,825
60	16,00431
65	17,50259
70	17,43448
75	16,68534
80	15,59569
90	13,62069
110	10,35172
120	8,92155

Dimensions of the tablet: thickness 1.58 mm, diameter 17.33 mm

The high relative dielectric permittivity of Sm doped $BaTiO_3$ could be explained by both Maxwell-Wagner interfacial polarization and dipole polarization. It is note worthy that anionic motion reoriention with in the host lattice thus induces dielectric polarization and may interact with conducting electrons, leading to significantly enhanced polarization. The vacancies are also of basic significance for high permittivity[34,35].

4. Conclusion

The synthesized Sm doped $Ba_{0.95}Sm_{0.05}TiO_3$ ceramics possesses high relative permittivity. The change in ε_r with temperature is typical for ferroelectric material. The registered maximum of the curve at 17.50259 is significantly higher than that of the untreated $BaTiO_3$- (approximately 2000 according to the most of literature data) and the Curie temperature - Tc, referring to the phase transition ferroelectric paraelectric (65°C) is definitely lower than the typical for barium titanate (120°C). The high relative dielectric permittivity as well as the curve ε_r = f (T°C) indicate that $Ba_{0.95}Sm_{0.05}$ TiO_3 ceramics is interesting as a supercapacitor for potential application in electronic devices requiring relatively high power and low energy as well as fast and frequent charge/ discharge cycles.

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Similarities between natural limestone filler and artificial bf slag filler used for the preparation of asphalt mixtures.

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Abstract: *In Romania, one of the most used filler for the preparation of asphalt mixtures are limestone filler. This is due to the limited requirements of the Romanian standards which impose precisely what kind of materials should be used to prepare asphalt mixtures, compared to the European standards who tempt to request physical-mechanical characteristics of the designed material. Its components can be chosen based on required specification.*
Considering these conditions, the usage of bf slag filler seems as good as the usage of limestone filler to obtain the same characteristics of asphalt mixtures.
Bf slag filler and limestone filler has similar properties and behaves similarly in asphalt mixtures. The study presents the similarities between these two types of filler, an artificial one obtained at the Liberty Galati steel plant, and a natural one, obtained in Arsita - Iacobeni quarry. Both can be used as a construction material in Romania, but the usage of artificial material is not quite common yet. This study presents the characteristics of fillers, both as a potential use in asphalt mixture formula.
To declare de values, bf slag was crushed in laboratory. The same tests were performed on filler and the obtained values were declared in accordance with the SR EN 13043:2008 standard.
Keywords*: BF SLAG FILLER, LIMESTONE FILLER, TESTS ON FILLERS.*

1. Introduction

In Romania, one of the most used filler for the preparation of asphalt mixtures are limestone filler. This is due to the limited requirements of the Romanian standards which impose precisely what kind of materials should be used to prepare asphalt mixtures, compared to the European standards who tempt to request physical-mechanical characteristics of the designed material. Its components can be chosen based on required specification. Considering these conditions, the usage of bf slag filler seems as good as the usage of limestone filler to obtain the same characteristics of asphalt mixtures. Bf slag filler and limestone filler has similar properties and behaves similarly in asphalt mixtures. The study presents the similarities between these two types of filler, an artificial one obtained at the Liberty Galati steel plant, and a natural one, obtained in Arsita - Iacobeni quarry. Both can be used as a construction material in Romania, but the usage of artificial material is not quite common yet. This study presents the characteristics of fillers, both as a potential use in asphalt mixture formula. To declare de values, bf slag was crushed in laboratory. The same tests were performed on filler and the obtained values were declared in accordance with the SR EN 13043:2008 standard.

2. Prerequisites and means for solving the problem.

The bf sludge has the ability to be used as construction material in Romania, considering the specifications of Directive 89/106/EEC on the harmonisation of the laws, technical regulations and administrative specifications of the Member States relating to products for constructions, the considerations of Ordinance 20/18.08.2010 on the establishment of measures for the uniform application of EU legislation harmonising the conditions for the marketing of products, as well as the specifications of HG 622/2004 with amendments and subsequent additions on the establishment of the conditions for placing construction products on the market. BF sludge is produced in the Liberty Galati plant and meets the characteristics of building materials according to specifications of SR EN 13043:2002/AC:2004. BF sludge is an artificial aggregate that can replace natural aggregates in the process of obtaining raw materials for construction industry. It is very commonly found at foundation works of various infrastructure works. As for the source of provenance, the bf sludge is obtained in the metallurgical industry, at the SC Liberty Galati steel plant, located in south-eastern Romania, in the city of Galati. The product obtained is temporarily stored; in the context of the current environmental issues, the need to capitalize this material, considered a waste, led to a much closer analysis of the physic-chemical properties of the bf sludge in terms of the standards mentioned above, studying the ability to use this material as well as the domain in which it can be used. Currently, the bf slag storage dump of the plant is in Galati municipality, on its own storage platform. SC Liberty Galati exploits the bf sludge, performing the processes of extraction, selection of sludge from storage dump, loading in crushing and sorting plants, sorting in different size fractions, storage of the materials of different size fractions obtained until revaluation. The crushed stone material is used mainly as granular raw material, as components of different material used in construction. Favourable effects of the use of bf sludge as building material includes reducing or even removing the dimensions of the storage dump, conservation of natural resources by limiting their use in industry (natural aggregates from quarries) and by redesigning the materials commonly used in construction works infrastructure, inclusion in the waste management plans of the sludge new methods for revaluation. So far, the ability to use bf sludge as filler has not been investigated in research of asphalt mixes formulas for bituminous layer.

The characteristics of the bf sludge obtained at SC Liberty Galati, from which it is desired the processing and obtaining of filler in the laboratory are stated in the certificate for factory production control, this being elaborated on different sorts. As raw material for obtaining filler it was used artificial aggregate sort 0/4 mm, which was obtained from blast furnace sludge, crushed, and sorted; the raw material is suitable for use in obtaining bituminous mixtures used in the construction of roads, airports, and other traffic areas, in accordance with the provisions of SR EN 13043: 2002 / AC: 2004, as it is stated in the certificate for factory production control. In this sense, on the aggregate of origin, laboratory tests were performed according to the current, and the values of the characteristics were determined by laboratory tests. Below are the characteristics of the sludge, relevant for demonstrating the ability to be used as a filler (not all the characteristics were determined on the 0/4 mm fraction).

Table 1: *Characteristics determined on blast furnace slag.*

No.	Characteristics of bf slag	Test values obtained bf slag
1	Volumetric mass of bulk (for fraction 0/63 mm)	1,51 Mg/mc
2	Pre-dried volumetric mass for fraction 0,063 / 31,5 mm	2,58 Mg/mc
3	Freeze-thaw resistance - for fraction 4/8 mm - for fraction 8/16 mm - for fraction 16/31,5 mm - for fraction 31,5/63 mm	 2,6 % 1,9 % 0,7 % 0,9 %
4	Chemical composition	

	- calcium oxide, CaO - silicon dioxide, SiO_2 - aluminium oxide, Al_2O_3 - iron oxide, FeO - magnesium oxide, MgO - manganese oxide, MnO - sulphur in the form of sulphides, S	34,0...46,0 % 31,0 ... 39,0 % 11,00 ... 21,00 % 0,2 ...0,7 % ≤ 8 % 0,1…1,9 % 0,4…1,0 %
5	Chemical character (determination made by SC Liberty Galati supplier)	the raw material is chemically inert, it is 100% ecological, it has no negative impact on the environment
6	Disintegration of granulated sludge from the furnace, made on the 0/63 mm lot, cooled in air from the dump (determination made by the SC Liberty Galati supplier)	after immersion in water, no piece shows cracks or disintegrations

Visually analysing the raw material that will be processed in the laboratory by grinding as a filler, we declare the following characteristics found through visual observations: the raw material is homogeneous, with a compact granular appearance, crystalline, without any impurities of any kind (such as: earth bulbs, coal, clays, etc.). The granules have a polyhedral appearance, are crushed, and have different dimensions included in the 0/4 mm granulation. To use the filler in the preparation of asphalt mixtures, the conformity check with the requirements of the standard, through initial type tests, must be carried out. These initial tests will be the starting point for the control of the future output. In the following, according to SR EN 13043, chapter 5, "Characteristics of fillers", we can find out what are the characteristics imposed on the supplemental fillers used in the preparation of the asphalt mix. In this sense, to identify the characteristics on the filler obtained from the bf sludge, we will determine the followings.

3. Solution of the examined problem.

3.1. Characteristics regarding granularity.

The granularity of the filler added to the mixture improves the granularity of the total mineral aggregate, in the way of reducing the volume of voids. Due to its fineness, the filler occupies part of the holes of the aggregates (fine, medium, and large), contributing to the creation of a more compact and more resistant mineral skeleton. The filler added to the asphalt, besides the granulometric role, also has the role of increasing the compaction of the mixture of natural aggregates, therefore an optimum granulation will be finally reflected in the degree of compaction of the mixture. The granularity is determined by gravimetric sifting through sieves, initially determining the fraction left on the sieves, after which were calculated the passes through those certain sieves, after which those passes were converted to percentages of the total analysed content. According to the tests carried out in the laboratory, the following values were obtained.

Table 2: *Granularity of blast furnace slag filler sample.*

No	Sieve dimension, in mm	Results, in %
1	Passing through sieve of 2 mm	100,00
2	Passing through sieve of 0,125 mm	87,90
3	Passing through sieve of 0,063 mm	76,30

3.2. Harmful fine particles (test using methylene blue).

The defect that can appear in the bituminous road layers due to the presence of impurities or water in the mineral aggregates, is the surface with pits; they represent holes with a diameter of about 20 mm, on small thicknesses or that can even extend all the thickness of the layer. Pits occurs either due to impurities in aggregates, or the presence of soft or altered rocks in the preparation of the asphalt mixture, or because of the presence of water in mineral aggregates. The laboratory tests were performed on the filler, which revealed the content of harmful fine particles as well as the moisture of the filler. According to the SR EN 13043 and AND 605 norms, the following limits were imposed as: for harmful fine particles: methylene blue value VBF 10 g / kg (category ≤ 10); humidity: max 1%.

Table 3: *Methylene blue test of blast furnace slag filler sample.*

No	Test carried out	Results, in %
1	Methylene blue test, on 0/2 mm fraction	0,40

3.3. Water content.

The moisture of the mineral aggregates plays an important role in the final mixing because a water content can lead to the formation of clods, to the uncomplete coating of the granules respectively to the formation of pits in the wear layer. Such a mixture put in place favors the infiltration of water into the layer. The humidity was determined by drying in the ventilated oven.

In this phase of analysis of the filler in the laboratory, due to the possibility of drying the material up to the constant mass, it is considered that the humidity is 0%, subject to the fact that it will be considered that when preparing the mixture, the humidity of the filler should not be less than 1%.

3.4. Pre-dried volumetric mass.

Pre-dried volumetric mass is a characteristic of the granular material that serves to further determine the actual volumetric mass of the asphalt mixture. Also, this spreads over other characteristics of the asphalt mixture in which the filler is used, and which will be analyzed later, determinations that are: the volume of voids in the mineral structure, the volume of voids in the asphalt mixture, the volume of voids filled with bitumen. Due to the influence on the pre-dried volumetric mass of the future mixture and implicitly of the volume of voids, this will be reflected in the degree of compaction, in the behavior of the mixture in the layer under the action of traffic.

Table 4: *Pre-dried volumetric mass of blast furnace slag filler sample.*

No	Test carried out	Results, in Mg/cm^3
1	Pre-dried volumetric mass	2,589

3.5. Porosity.

The porosity of the filler has a great influence on the asphalt mixing behavior. Due to the micropores in the composition of the filler granules, they can have a reduced hardness, which is expressed by the high porosity. The high porosity filler can change the bitumen properties. The high porosity of the filler is mainly given by the content of impurities in the form of clay (determined by the methylene blue value method) as well as the compounds Fe_2O_3 and Al_2O_3.

Table 5: *Relevant compounds for porosity of blast furnace slag filler sample*

No	Characteristics determined	Results, in %
1	Clay content (methylene blue test method), VBF	0,40 grams of methylene blue solution / kg of fraction 0/0,2 mm
2	Content of Fe_2O_3 compounds	0,20 ...0,70 %
3	Content of Al_2O_3 compounds	11,00 ... 21,00 %

3.6. Water solubility.

For the determination, a filler sample was prepared, with a mass of 25 grams, after which it was dried to a constant mass at 110 degree Celsius. The test samples were placed in two 500 ml Erlenmeyer glasses, weighed together with the contents and their weigh was recorded. The mass of the dry filler from each glass resulted from the difference. In each glass a quantity of water equal to half the mass of the test tube was added. The coated specimens were stirred continuously to avoid sedimentation for 24 h. After the time expired, the liquid was filtered from above, leaving the residue in the glasses. The residue left in both the glass, the funnel and the filter paper were dried and cooled to room temperature and then weighed again.

Table 6: *Water solubility of blast furnace slag filler sample.*

No	Test carried out	Results, in %
1	Water solubility	0,60

3.7. The specific surface of filler by Blain test.

The specific surface of the filler represents the total surface of the filler particles contained in its mass unit. The surface of the filler always contains cracks, pores, bumps of microscopic dimensions. The granules are porous, the pores being both on the surface and closed, labyrinthine, connected between them. The closed porosity does not contribute to the adsorption phenomenon in the filler-binder mixture, while the open porosity, specially the one with dimensions up to 100 μ, represents a relatively large surface compared to the total surface of the granule, which will influence the bitumen absorption phenomenon at the top of the filler granules. Due to the phenomena that appear at the filer- bitumen interface, the knowledge of the specific surface of the filer constitutes an appreciation of its quality. The larger its specific surface, the more the influence of the structure of the filler on the bitumen is manifested. In the asphalt mixture, the influence of the specific surface correlated with the fineness of the filler granules can be negative, because the exceptionally fine granules can lead to particle agglomerations in the mixture. These agglomerations have the effect of reducing the compactness of the asphalt mixture. In practice, these effects have been found predominantly in the asphalt mixtures used in the wear layer, especially at the high dosage of filler of the mineral mixture, between 7 ... 12%. The other granular materials in the composition of the asphalt mixture have extraordinarily little influence regarding the specific surface, the predominant being this characteristic of the filler.

On the analyzed sample, the specific surface was determined by Blaine test, determining the fineness.

Table 7: *Finesse by Blaine test on blast furnace slag filler sample.*

No	Test carried out	Results, in cm^2/g
1	Finesse (Blaine method)	5086

3.8. Emissions of radioactive substances.

The material is chemically inert, 100% ecological, does not have a negative impact on the environment.

4. Results and discussion.

The results of the two materials, one – bf slag filler and one - natural rock filler existing on the market, are comparable, and because the filler obtained from bf sludge complies with the requirements of the standard on which it was verified, SR EN 13043, we can conclude that it can be used in the preparation of asphalt mixtures, to be analyzed the way of his behavior in interaction with bitumen, as well as in the total compounds of asphalt mixture.

Table 8: *Comparative analysis on blast furnace slag filler sample and limestone filler*

No	Characteristics	Values on bf sludge / limestone filler	
1	Pre-dried volumetric mass	2,589Mg/mc	2,750Mg/mc
2	Granularity - passing through sieve of 2 mm - passing through sieve of 0,125 mm - passing through sieve of 0,063 mm	100,00% 87,90% 76,30%	100,00% 93,20% 80,21%
3	Harmful fine particles content (VBF)	0,40%	2,00%
4	Water content	0,00%	0,40%
5	Blain test. Specific surface	5086cm^2/g	4276cm^2/g
6	Water solubility	0,09%	0,17%
7	Chemical composition: - calcium oxide, CaO - silicon dioxide, SiO_2 - aluminum oxide, Al_2O_3 - iron oxide, FeO - magnesium oxide, MgO - manganese oxide, MnO - sulfur in the form of sulfides, S	 34 – 46 % 31 – 39 % 11,0 - 21 % 0,2 ...0,7 % ≤ 8 % 0,1… 1,9 % 0,4…1,0 %	 51,54% 4,25% 1,67 % 0,47 % 0,10% - 0,09%
8	Chemical character	the raw material is chemically inert, it is 100% ecological, it has no negative impact on the environment	limestone rock

Like the other components of asphalt mixtures, the filler is dosed in precise quantities. When the dosage is correctly chosen, the filler increases the specific surface of the natural aggregate, increases the mixture compactness, and by the filler- bitumen mixing mixture which is made when mixing, the resistance of the asphalt mixture is increased (the stability) and reduces the deformation of the mixture at high temperatures. The role of the filler in asphalt mixtures is given both by the physical, mechanical, and chemical characteristics of the filler as well as by its dosage in the mineral skeleton and by the ratio between the filler and bitumen. As the ratio is at the upper limit imposed, both the physical-mechanical strengths of the mix as well as durability, increase. The thickness of the bitumen film that covers the filler particles, thickness which is determined by the bitumen dosage in the total mixture, influences the characteristics of the mixture.

From the tests carried out directly on filler, its characteristics are expressed, which refers strictly to the material and by determining the characteristics of the asphalt mixtures it can be deduced if the filler has fulfilled its role in the mixture. Dosed correctly, the filler performs its role in asphalt mixtures, but the excess filler can be harmful, as follows: very often it is possible to be formed in the composition of asphalt mixture clod of filler, or the mixture itself can be exceedingly difficult to work with; this can lead to insufficient compaction of the layer which favors the infiltration of water into the gaps between the granules, and consequently their disassembly. In any case, granules of mineral aggregate must be coated with a thin film of bitumen. The thicker the film, the more deformed the mixtures and the shear resistance decreases. Obtaining a fine bitumen film can be done by filing.

Known assumptions regarding the influence of fillers on the asphalt mix are the stability and creep of the asphalt mixtures vary significantly with the filler dosage, the filler improves the binder viscosity, because of its granularity, reduces the volume of voids in

the asphalt mixture, the filer - bitumen interaction (the filer - bitumen ratio) has a significant influence on the physical-mechanical properties of the asphaltic mixtures. If the filler-bitumen ratio is increased, keeping the percentage of binder constant, then the mixture obtained will be more rigid, will have a high stability and low deformation, and during the paving process the mixture will require mixing and a more energetic compaction. The increased rigidity is given by increasing the softening power of the filamented bitumen and reducing the volume of apparent voids. The excess filler generally leads to a difficult to work mix, possibly even with uncoated granules, which favor water penetration. If the ratio of filler-binder decreases keeping the percentage of binder constant, then the mixture will be more elastic, will have a low stability and a high deformation. The mixture will deform at the action of a low force, especially at high temperature. Also, a low content of filler favors the leakage of the binder from the surface of the granules due to its low viscosity.

Therefore, it can be easily concluded that both the physical-mechanical and chemical properties and the filler dosage will have an influence on the characteristics of asphalt mixtures. Due to the comparable test results on natural and artificial filler, we expect that both types of fillers will fulfil their role in operation.

5. Conclusions

The possibility of using a material from the metallurgical industry, material that is currently stored in dumps in the SC Liberty Galati space, will offer future advantages such as: the guarantee of the elimination of these deposits, introduction in the life cycle of some products from warehouses, avoiding environmental problems and including penalties for deposits. By using the steel waste obtained from the steelworks, favorable results can be obtained both in terms of economic development as well as the valorization of a material that, if is not being used, is treated as waste.

Currently, there is a tendency to exploit bf sludge waste, due to its ability to be used as an artificial aggregate in the construction industry, bf sludge being processed (crushed and sorted) in different dimensions and used as granular material, especially in foundations. Blast furnace sludge is the result of the technological process of obtaining castings, by granulation. During the technological process, the sludge is liquid and has a temperature of approximately 1480 degrees Celsius. The sludge granulation process is obtained by hydrodynamic shock resulting in the granulated sludge product. Also, the granulated sludge can be crushed and sorted later to obtain the sorts. After granulation in the water of the sludge, it is removed from the basin with the excavators and stored on platforms, to drain water.

For the bf sludge filler producer, the possibility of using this material as a raw material gives it the opportunity to: partially substitute the fuels used to support the raw material (stone quarrying), to be actively involved in the procedures for the protection of the environment. For the society, the possibility of using the granulated sludge will bring benefits amount: conservation of natural resources (quarry rock, the most used rock in Romania in the production of filler), reducing the impact on the environment, by removing the dumps from the deposits, avoiding overcrowding of the material in deposits.

As it results from the tests carried out and from the theoretical considerations described in this chapter, the filler plays an important role in the construction of asphalt mixtures. The fineness properties and the inert character of the filler highlight the process of inertial interaction in the mixture. Therefore, it is important to establish the characteristics of the filler before placing it in the mixture, in order not to compromise the quality of the mixture made. We can conclude after this study, the role that the filler has in mixtures and the effect of its characteristics on the prepared mixture, as follows: it leads to the improvement of the granularity of the mineral mixture, it leads to the delay of the aging phenomenon of the bitumen, it leads to the increase of the stability of the asphalt mixture and to the decrease of the deformation, it improves the adhesive of the binder, the porosity of the filler influences the binder dosage and the mixing behavior; if necessary, in order to decrease the porosity of the filler, it is possible to use activating substances in its grinding process (in production), the porosity of the particles is affected by their shape; the particle shape also influences the adhesive bonding to the granule surface

6. References

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2. Ordinance 20/18.08.2010 on the establishment of measures for the uniform application of EU legislation harmonizing the conditions for the marketing of products.
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Study on HD cameras with CMOS sensor degradation upon ionizing radiation exposition

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Abstract: *In this paper we have exposed 3 HD cameras with CMOS sensor in long time experiment at different doses and exposition time with γ radiation from 2 sources of ionizing radiation – cobalt 60 (Co60) and cesium 137 (Cs137) at room temperature imitating the working conditions of "hot cell" premises. All components of the used camera are without radiation reinforcement, excluding the lenses. During the experiment, we found degradation of the irradiated cameras. As the absorbed dose increases, the image becomes brighter. Furthermore, experimental results demonstrated decreasing in signal-noise ratio (SNR) with increasing the absorbed dose. We confirmed that the HD industrial cameras can operate in ionizing radiation environment with moderate decrease of SNR (3,5dB. This experiment is valuable and can provide information for selection of cameras working in ionizing radiation environment.*
Keywords*: CMOS IMAGE SENSOR, RADIATION DEGRADATION, DOSE RATE, HD CAMERA*

1. Introduction

Video cameras are widely used in surveillance and video inspections in ionizing radiation environment, during interruptions of nuclear reactors, as well as in space research in satellites. Radiation gamma radiation upon electronic elements reduces their operational life depending on their total absorbed dose. This fact obliges the introduction of radiation control, which contains monitoring of the dose rate at the points where the cameras are installed. In the good practices there is no normative requirements for the indication of threshold for gamma radiation resistance of industrial electronic devices and elements.

The camera is complex opto-mechanical and electronic device which consists of three main parts:

Optical. With its help, the reflected light rays from the captured objects are projected on a special surface, which converts them into electrical signals and then passes to the electronic processing unit.

Electronic unit. There are several modules included in the electronic unit. Some of them control the optical system, others process the received electrical signals from the optical system in a suitable form communication or recording. A separate module controls the camera's recorder.

Viewfinder. This is a device that allows the operator to see where it is aimed and what the camera is currently shooting, and provides additional information about recording, speed, aperture, focus, white balance, battery status, volume, etc.

Recording device. Often this is a stand-alone module (even with some types of cameras it is missing), with which the video signal is transferred to a durable medium – magnetic tape, digital memory such as cards, DVD, hard disk, flash memory or cloud.

Nowadays, two competing technologies are mainly used in the production of light-sensitive arrays. The first is simpler in a number of ways and more promising is the CMOS (Complementary Metal-Oxide-Semiconductor) technology. The leader in the digital photo market is CCD (Charge-Coupled Device) technology. More labor-intensive to manufacture, CCDs are used in the vast majority of digital cameras. CMOS arrays are most commonly used in cameras.

The basis of the array, made by CMOS technology, are field-effect transistors, which change their state during illumination, which change their state during illumination, preventing the flow of electric current through the terminals, or vice versa, amplifying the signal. The electronic circuit of the camera records changes in the state of Yacheek array and based on this constructed image.

CMOS arrays are characterized by reduced power consumption compared to CCD matrices. On the other hand, the resolution, dynamic range and noise immunity of CMOS arrays are lower than that of CCDs. This is explained by the complexity of the device, as well as the lower light sensitivity of the field-effect transistors of the elements. Used in low-end cameras in the beginning, CMOS arrays are designed as a large hybrid chip, on the board of which are mounted many service circuits of the camera. These are the analog-to-digital converter (ADC) and the electronic shutter, the schemes for white balance and image compression.

Another positive side of CMOS arrays is their stability and durability. The reason is again the use of field-effect transistors as light-sensitive elements, in the larger sizes of each element and in the high manufacturability of the production. The microscopic pixels of the light-sensitive arrays react only to the intensity of the light falling on them. To get an image that is close to the quality of a movie photo, the digital camera must also distinguish colour shades. To increase the accuracy of the array operation (improving the SNR) by increasing the light sensitivity, each pixel has a converging microlens focusing the light flux. This is especially true for CMOS arrays, where without such lenses it is difficult to achieve the required image quality.

Disadvantages of CMOS arrays are low pixel fill factor, which reduces the sensitivity (the effective surface of the pixel is ~ 75%, the rest is occupied by transistors) and high noise level (due to the fact that even in the absence of light through the photodiode significant current), the reduction of which complicates and increases the cost of technology.

[1,2,3,4]. CMOS sensors are widely used in video inspections due to their higher durability compared to conventional CCD sensors [5,6,7], and their damage is acceptable in environments with low levels of ionizing radiation [8,9]. The analysis of ordinary CMOS cameras will provide valuable information in the design and selection of video systems in an environment with ionizing radiation. Therefore, it is necessary to study and analyze the degradation of ordinary CMOS cameras[10,11].

Radiation damage includes total ionizing dose (TID) when irradiated with different doses, displacement dose (DD) and single-event transient (SET) damage. TID degradation causes performance degradation, including CMOS sensor malfunctions, so the impact of this type of damage must be most strongly considered when using CMOS HD cameras. The Goiffon study compares damage to CMOS sensors, TID versus DD, by photon irradiation [12]. Leonello Servoli's study describes the progressive damage of CMOS sensors without ionizing radiation protection [13]. Zujun Wang studies the damage of CMOS (3T) sensors made with 0.35-μm technology, subjected to TID irradiation at 7.2 and 1800.0 Gy (Si) / h [14]. Although there is considerable research on the damage caused by TID on CMOS sensors, few articles focus on the effect of the absorbed dose upon the image quality of HD cameras with CMOS sensors.

2. Requirements to the system's elements

The choice of controllable PTZ cameras for effective video surveillance is determined by a number of complex factors, but the main one is their greater flexibility and the ability to monitor at a wider angle. Known as controllable CCTV cameras, these systems provide the convenience of being able to focus on the right details

in the observed object. For example, you will be able to get both a panoramic picture of the observed object and a detailed one of a certain segment from it, through which you want to analyze in detail. Another advantage of controllable cameras is their ability to easily monitor a shifting or moving object. The biggest benefit of controllable cameras is providing a more reliable way of monitoring an object is their dynamics. Thanks to it, they act as several stationary cameras and offer far more important information than that which can provide us with a camera from some of the static models.

Controlled cameras are widely used where it is necessary to cover large areas and specifically fixed parts of the areas with video surveillance.

Sources of ionizing radiation are sealed spent radioactive sources subject to disposal. In the course of the technological process to be monitored, the main source of ionizing radiation remains this spent, over which radioactive aerosols are also released. The components of the video system which may be contaminated with radioactive substances shall be designed so as to be easily deactivated by chemical or mechanical means.

3. Requirements to the system's elements

Cameras: the proposed model captures excellent video with 1080p resolution (1920 x 1080) at 25 frames per second. It is possible to change the shooting mode from full HD to HD or SD. The case is reliably and securely built to withstand the extreme temperature range from -40 to +70 ºC, and also has 6 kV lightning protection. In addition, the device has the IP 66 standard – it has been tested for durability in contact with water and dust, which makes it extremely suitable for installation requirements.

The cameras are equipped with a motorized lens with a range from 2.7mm to 11mm. with a viewing angle from 112.5° to 39°, four times the powerful optical zoom and 16 times digital, thanks to which you can observe various objects from the in the treatment area. As well as a rotating PTZ mechanism, whose functions provide a large monitoring range and high detail. PTZ means pan-tilt-zoom, i.e. rotation (horizontal), tilting (vertical) and zoom. The rotation can be 355 degrees at an inclination of -0° to + 90°.

The cameras are connected to the DVR (digital video recorder) via a coaxial cable and can be controlled remotely via a controller and OSD menu located outside the "hot cell".

4. Requirements to the system's elements

The experiments were performed for a long time at different doses and exposure times with γ radiation from two types of sources - cobalt 60 (Co60) and cesium 137 (Cs137) at room temperature, thus simulating the real working environment of a premise type "hot camera ". The dose at the test position was calibrated with a Silver Dichromate Dosimeter before irradiation.



Fig. 1 *Location of the three cameras in the testing area.*

For the experiment are used three cameras, which are located at different distances from the sources of ionizing radiation (Figure. 1). The distances are as follows: Source-Camera 1 – 120 cm, Source-Camera 2 – 220 cm; Source-Camera 1 – 180 cm. The cameras are attached to the walls of the room where the experiment is performed. The cameras have serial numbers from A01 to A03, all CMOS sensors are from one batch. The test of each camera is performed at the same time. The experimental conditions and serial numbers of the cameras are presented in Table 1. All cameras are powered by 12 V DC and transmit a real-time video signal.

There are 21 exposures to ionizing radiation. Parameters of the expositions are given in table 1.

Table 1: *Parameters of the expositions.*

№	Type of the source	Activity of the source, Bq	Exposition time, s	Absorbed dose camera 1, Gy	Absorbed dose camera 2, Gy	Absorbed dose camera 3, Gy
1	Co60	100	600	1300	387	578
2	Co60	120	240	624	186	277
3	Co60	800	180	3120	928	1387
4	Co60	1500	240	7800	2321	3467
5	Cs137	300	210	1365	406	607
6	Co60	900	300	5850	1740	2600
7	Cs137	1000	450	9750	2901	4333
8	Cs137	700	300	4550	1354	2022
9	Co60	750	360	5850	1740	2600
10	Co60	500	600	6500	1934	2889
11	Cs137	550	300	3575	1064	1589
12	Cs137	400	180	1560	464	693
13	Cs137	600	120	1560	464	693
14	Cs137	2000	600	26000	7736	11556
15	Co60	1800	210	8190	2437	3640
16	Co60	1500	630	20475	6092	9100
17	Cs137	350	570	4322	1286	1921
18	Co60	700	330	5005	1489	2224
19	Co60	600	300	3900	1160	1733
20	Cs137	1100	450	10725	3191	4767
21	Cs137	1800	540	21060	6266	9360

Data from the tested cameras are recorded continuously during irradiation to measure the SNR of the cameras before, during and after irradiation, the video signal includes images under all three conditions. At the end the camera degradatin is calculated according to the European Machine Vision Association (EMVA) 1288 standard[15].

5. Conclusions

After exposure with ionizing radiation of the three cameras, degradation is observed to varying degrees in each of the cameras – burned pixels, increased SNR and the overall fading of the camera image. This means that the dynamic range of the image decreases and the dynamic characteristics of the system deteriorate, i.e. the image quality decreases. The results are presented in Table 2. Results are measured in batches of 7 expositions.

Table 2: *Degradation of tested cameras.*

№ camera	Distance form the source, cm	Number of burnt pixels, pcs.	Increase of SNR, dB	Overall fading of the image, %
	After exposition №7			
1	120	88	1,7	1,72
2	220	19	0,51	0,53
3	180	33	0,76	0,91
	After exposition №14			
1	120	112	2,5	2,53
2	220	35	0,75	0,75
3	180	51	1,12	1,13
	After exposition №21			
1	120	143	3,47	3,51
2	220	57	2,39	1,17
3	180	93	1,56	1,83

6. Conclusions

In this paper we have studied the degradation of an HD camera with a CMOS sensor after several expositions with ionizing

radiation from sources of γ radiation from two types of sources – cobalt 60 (Co60) and cesium 137 (Cs137) at different doses and exposure times at room temperature. The behaviour of the examined cameras showed degradation.

During exposition with γ radiation from Co60 and Cs137 one of the visible effects is that the more the cameras are exposed, the greater the degradation is. Also, as the distance decreases, the degradation of the cameras increases. More experiments will be conducted in the future to confirm the conclusions in this article.

This means that the dynamic range of the image decreases and the dynamic characteristics of the system deteriorate, i.e. the image quality decreases. This effect is well illustrated by visual observation[16], [17].

By analyzing the SNR of the image, we find that the decrease in the SNR changes with increasing of exposition and the absorbed dose, respectively. Even so, the reduction in SNR is still small, within 3.5 dB. Therefore, HD industrial cameras with CMOS sensors can be used under certain conditions in an environment with ionizing radiation, where ionizing radiation can lead to moderate damage[18].

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