

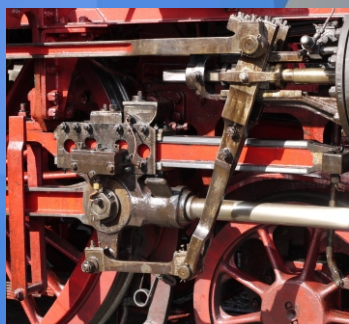
INTERNATIONAL SCIENTIFIC JOURNAL

INDUSTRY 4.0

ISSN (PRINT) 2543-8582

ISSN (WEB) 2534-997X

YEAR II ISSUE 4/2017



①



②



③



④



PUBLISHED BY
SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
BULGARIA

INTERNATIONAL SCIENTIFIC JOURNAL

INDUSTRY 4.0

YEAR II, ISSUE 4 / 2017

ISSN PRINT 2543-8582, ISSN WEB2534-997X

PUBLISHER

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY 4.0"

108, Rakovski Str., 1000 Sofia, Bulgaria

tel. (+359 2) 987 72 90,

tel./fax (+359 2) 986 22 40,

office@stumejournals.com

WWW.STUMEJOURNALS.COM

EDITOR IN CHIEF

Prof. D.Sc. Georgi Popov, DHC, Technical University of Sofia, BG

Prof. Dr. Dr. Jivka Ovtcharova, DHC, Karlsruhe University of Technology, DE

EDITORIAL BOARD

Acad. Igor Bychkov, RU

Cor. member Alexey Beliy, BY

Cor. member Svetozar Margenov, BG

Prof. Alexander Afanasyev, RU

Prof. Alexander Guts, RU

Prof. Andrzej Golabczak, PL

Prof. Andrey Firsov, RU

Prof. Bobek Shuklev, MK

Prof. Boris Gordon, EE

Prof. Branko Sirok, SI

Prof. Claudio Melchiorri, IT

Prof. Cveta Martinovska, MK

Prof. Dale Dzemydiene, LT

Prof. Dimitar Yonchev, BG

Prof. Dimitrios Vlachos, GR

Prof. Galina Nikolcheva, BG

Prof. Gerard Lyons, IE

Prof. Henrik Carlsen, DK

Prof. Idilia Bachkova, BG

Prof. Idit Avrahami, IL

Prof. Iurii Bazhal, UA

Prof. Jürgen Köbler, DE

Prof. Jiri Maryska, CZ

Prof. Katia Vutova, BG

Prof. Lappalainen Kauko, FI

Dr. Liviu Jalba, RO

Prof. Luigi del Re, AT

Prof. Majid Zamani, DE

Prof. Martin Eigner, DE

Prof. Michael Valasek, CZ

Prof. Milija Suknovic, RS

Prof. Miodrag Dashic, RS

Prof. Mladen Velev, BG

Prof. Murat Alanyali, TR

Prof. Nina Bijedic, BA

Prof. Ninoslav Marina, MK

Prof. Olga Zaborovskaia, RU

Prof. Pavel Kovach, RS

Prof. Petar Kolev, BG

Prof. Peter Korondi, HU

Prof. Peter Sincak, SK

Prof. Petra Bittrich, GE

Prof. Dr. Predrag Dasic, RS

Prof. Radu Dogaru, RO

Prof. Raicho Ilarionov, BG

Prof. Raul Turmanidze, GE

Prof. René Beigang, DE

Prof. Rozeta Miho, AL

Prof. Sasho Guergov, BG

Prof. Seniye Ümit Oktay Firat, TR

Prof. Sreten Savicevic, ME

Prof. Stefan Stefanov, BG

Prof. Svetan Ratchev, UK

Prof. Sveto Svetkovski, MK

Prof. Tomislav Šarić, HR

Prof. Vasile Cartofeanu, MD

Prof. Vidosav Majstorovic, RS

Prof. Vjaceslavs Bobrovs, LV

Prof. Inocentiu Maniu, RO

Dipl.-Kfm. Michael Grethler, DE

CONTENTS

DOMINANT TECHNOLOGIES IN “INDUSTRY 4.0”

HORIZONTAL AND VERTICAL INTEGRATION, AS A REQUIREMENT FOR CYBER-PHYSICAL SYSTEMS IN THE CONTEXT OF INDUSTRY 4.0

K.Chukalov. PhD Student 155

MATHEMATICAL MODELING OF ENERGY INTEGRATED ATAD SYSTEM FOR THEIR SUSTAINABILITY IMPROVEMENT

Prof. Dr. Vaklieva-Bancheva N. G., Assist. Prof. Dr. Vladova R. K., Assist. Prof. Dr. Kirilova E. G. 158

IMPROVING THE PRECISION OF PLANT RESPONSE BY MODELING THE STEADY STATE ERROR

MSc. Dushko Stavrov, Assist. Prof Goran Stojanovski, Prof. DSc Stojche Deskovski 161

REACHABILITY PLANNING OF INDUSTRIAL ROBOT IN CONCEPT OF DIGITAL FACTORY

doc. Ing. P. Košťál, PhD. & doc. Ing. Š. Václav, PhD. & Ing. D. Michal & Ing. Š. Lecký 165

DOMINANT TECHNOLOGIES IN “INDUSTRY 4.0”

DIGITAL IMAGE CORRELATION ANALYSIS OF CFRP DURING COMPRESSION TEST

C.Barile, C.Casavola, T.Mizzi, G.Pappalettera, C.Pappalettere 169

SIMULATION AND MOTION CONTROL OF INDUSTRIAL ROBOT

Yaser Alaiwi, Aşkın Mutlu 175

INFORMATION - CALCULATION METHOD FOR ENERGY EFFICIENCY RADIANT HEATING SYSTEMS IN INDUSTRIAL PREMISES

Hristozov Daniel Eng., Madzharova St. Asst. Prof PhD., Eng., Bozukov N. Prof. PhD, Eng., Petrova T. Assoc. Prof. PhD, Bakalov I. Asst. Prof. PhD 179

FULL USE OF MATHEMATICS – FOUNDRY

Bushev S., Associate Professor, PhD, Eng. 183

BUSINESS & “INDUSTRY 4.0”

THE POSSIBLE IMPLICATIONS OF TAX REFORM IN RUSSIA

Prof. Dr. Elena Yrevna Sidorova 187

SCIENTIFIC-METHODOLOGICAL PROVISIONS OF FORMATION OF A VIRTUAL SEGMENT OF THE INFORMATION MARKET

Doctor of Economic Sciences, Professor, Zhavoronkova G., PhD (Economics), Associate Professor, Zhavoronkov V. 189

INTEGRATING OPEN DATA INTO COMPANIES’ BUSINESS MODELS FOR FOSTERING DIGITAL TRANSFORMATION

Antonova A., Yordanova S. 193

SOCIETY & „INDUSTRY 4.0”

INDUSTRY 4.0 and TURKISH NATIONAL INNOVATION SYSTEM: CHALLENGES and PROSPECTS

Erkan Erdill and Şeyda Ertekin 197

HORIZONTAL AND VERTICAL INTEGRATION, AS A REQUIREMENT FOR CYBER-PHYSICAL SYSTEMS IN THE CONTEXT OF INDUSTRY 4.0

K.Chukalov. PhD Student.

Faculty of Mechanical Engineering – Technical University Sofia, Bulgaria

Konstantin_chukalaov@abv.bg

Abstract: The development in the information and communication technologies conditions the beginning of the fourth industrial revolution (FIR). The current report considers the peculiarities of the cyberphysical systems, as the basis of the fourth industrial revolution (Industry 4.0) and the need of their inner horizontal and vertical integration.

.Keywords: INDUSTRY 4.0, INFORMATION-TECHNICAL SYSTEM, STRUCTURAL REORGANIZATION

1. Introduction

The key elements of the fourth industrial revolution are the cyberphysical systems (CPS), through which networks are created for the self-regulation of spatially distributed production resources. The introduction of the principals of this revolution in production requires the creation of conditions for its normal functionality. The vertical and horizontal cooperation between the machine and the internet, machine – person, and machine - machine along the value chain in real time, are the basis of the production cyber system and determines the actuality of the problem.

2. Theoretical foundations

The cyberphysical systems are „intelligent systems”, which cover the hardware and software, as well as the effectively integrated physical components, which interact closely with each other, so they can detect any change in the state of the real world, as defined by the “National institute of Standards and Technology” (NIST). In the world's scientific literature there is no “sharp” restriction on the notion of cyber-physical systems regarding the tendencies and ways in the development of complex informational – communication technical systems. Cyber-physical systems refer to physically mechanical complexes with IT systems, hardware and software digital components with mechanical or electronic components that can autonomously communicate with each other.

The creation of a cybernetic environment is imperative so it can provide:

- Functional compatibility: The capability of cyber-physical systems (for example – intelligent machines), people and “intelligent factories” (Smart Factory) so they can exchange information between “the internet of things” and “Internet services”;
- Virtual compatibility: The creation of a virtual copy of a “Smart factory”, which is created by connecting the data collected from physical sensors with virtual models of the production processes, specialized software and so on;
- Decentralized management: The ability of Cyber-physical systems, Separate components and so on, within the margins of one “smart factory” to make independent decisions;
- Data transfer in real time: The ability of gathering and analyzing data while making decision in real-time;
- Service orientation: Through the Internet of Services, people and “smart users” are provided with services;
- Modularity: Flexible adaptation of “Smart factories” to the changing requirements, either by replacing or expanding of individual or accession modules;
- Flexibility: Individualization of mass production, by using the principals of mass production by a customized system of planning.

3. Implementing of cyber-physical systems on the basis of horizontal and vertical integration

Interaction between implemented systems based on highly specialized software and specialized user interface, which are integrated in digital networks create an entire new world of the systems functionality for the horizontal and vertical integration.

Horizontal integration: Through the integration of the Network IT technologies and manufacturing systems an exchange of data and information must be established between the firms and the geographically remote sites across the value chain. Therefore by “Horizontal integration” an integration of various information technology systems in the production and automated equipment for various stages of the production and planning process is understood.

Vertical integration: The “internet of things” and services grant immediate access to IT and production systems. Through vertical integration of data and information directly from the workplace by controlling and operating on a production and corporate level, the data is processed and as a result, adequate information about the management is returned. Therefore “Vertical integration” can be understood as the integration of information technologies in IT systems in various hierarchy levels in production and automation equipment. (For example: sensors, level of management, level of production management). The vertical and horizontal Cooperation between machine and internet, machine and person and machine to machine on the chain of value, in real time, is the basis of the production cyber system.

In the transition to cyber-physical systems, implemented systems, production, logistic, engineering, coordination and management processes as well as internet services can be added, which with the help of sensors gather physical data and interact with physical processes with the help of digital networks, connected with each other. They can use current data and services, as well as multimodel interfaces person – machine.

On fig.1 the stages of development of the cyber-physical systems. It can be assumed that this concept will be transferred by a single factory to a whole network of sites with added value in the future, for the manufacturing of intelligent products or for the compensating of the production capacities, acc. to Scheer[1].

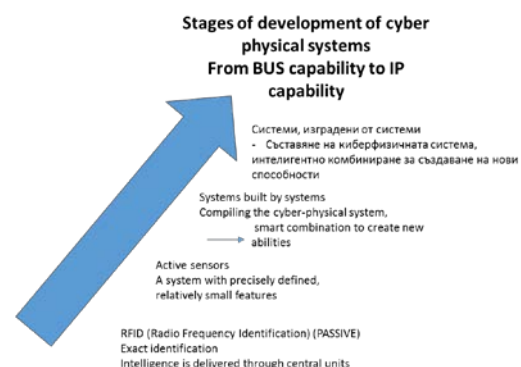


Fig.1. Stages of development of the cyber-physical systems

3.1 – Stages of development of the cyber-physical systems

The development of the cyber-physical systems can be characterized with three phases of implementation, namely:

- First Generation of CPS, which includes identification technologies, as RFID tags, which allow a unique identification.
- The storing and analyzing of information is a centralized service.
- The second generation of CPS is the equipped with sensors and executive mechanisms with a limited set of functions.
- The third generation can store, analyze data and is equipped with various sensors and executive mechanisms, all which are executed in compatible networks, acc. to Bauernhansl, Hompel, Vogel-Heuser [2].

This is a production revolution in terms of expense and saving time. The intelligent manufacturing brings with itself many advantages in comparison with the conventional manufacturing, or that is the intelligent production revolution. The cyber-physical systems require a network of informational technologic and production systems to be build, trough domains and hierarchy boundaries. The implementation of the cyber-physical systems in the production, for the establishment of an intelligent manufacturing is the second key moment.

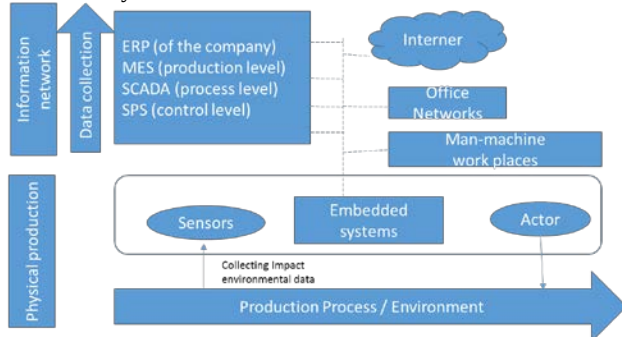


Fig.2 Implementing of the cyber-physical system in manufacturing.

Because of that, interoperable communication interfaces and standard protocols are required. Furthermore, the products of manufacturing are intelligent, they carry information from their own manufacturing in machine-readable form (for example RFID chips), that way they can coordinate their own manufacturing actions. In order to meet the requirements for communication in real time, and also so that the cyber-physical systems meet the requirements for high availability and for a longer life cycle they must be built with standard IT elements. In that way, in order to establish a decentralized data collection, they must be continuously integrated into IT systems – best case scenario, included in Enterprise Resource Planning (ERP), manufacturing management (MES), systems for supervision (supervisory control and data acquisition, SCADA), programmable controllers (SPS) and integrated systems for vertical and horizontal integration. The structure of informational streams and networks is of most importance for the cyber-physical manufacturing as a whole. On pic.2 the transition from existing to cyber-physical systems is shown.

In this transition the cyber-physical systems usually include: Embedded systems, production, logistics, engineering, coordination and management processes, as well as internet services, whom with the help of sensors gather physical data and interact with physical processes with the help of digital networks connected with each other. They can use all current data and services, as well as multimodel interface person - machine. The production systems gradually evolve from planning systems (ERP, MRP, MRPII) and operational management of production (MES) to an integrated working platforms, which encompass business tools, supply and asset management, production schedules and solutions for an optimization of the production processes.

The cyber-physical systems are an openly social-technical systems and allow a number of new features, services and properties to be performed. Therefore one of the most important tasks in the field of design, development and management of cyber-physical systems is the question of co-operation between the cyber-physical system and the human factor. The questions which are with most importance in the context are the identification and modeling “awareness of the situation” the human experience with such kind of systems, the environment, as well as reflecting the changes.

4. Methodology for the research of the factors for vertical and horizontal integration.

In relations to the better structuring of the problem of accounting for the requirements of Industry 4.0, the influencing factors can be grouped in the following directions:

- Factors influencing on the physical wear and tear, which leads to reducing their capacity capabilities. This group of factors are directly related with the requirements for Modularity (flexibility);
- Factors influencing on the innovation aging, which can be only partial, without having any affect on the on the productivity, or full innovation aging, which has a relative impact on productivity. This group of factors are directly related with the requirements from for operational compatibility;
- Factors influencing on the level of elements of the technical system, such as automation devices (Level / degree of automation), automated complexes (Level / degree of automation), self-regulating systems, technical compatibility (Level / degree of elements in the system), Base and bonding models. These factors are directly related with the requirements from Industry 4.0 for Decentralization;
- Factors influencing on the level of the technical system, related to modules, complexes and systems such as a Modular Network, complex network and a system network. This group of factors is directly related to the with the requirements from Industry 4.0 for information in real time, virtualization and orientation towards services;
- Factors related to the flexibility of the system (flexible adaptation towards the changing requirements: replacement, expansion and more.) All those factors are connected with the requirements from Industry 4.0 for modality (flexibility);
- Factors related to the automation of the elements and components of the system. (CAD/CAM/CAE, vertical and horizontal diversification and software). This group of factors is related with modality (flexibility), information in real time, virtualization and decentralization.
- Factors related to the operational and functional compatibility of the elements and components of the system, decentralization and usage of the information in real time;
- Factors related to the horizontal and vertical compatibility of the system (technological and business operations in a horizontal direction, technological and business operations in a vertical direction, targeted network models for compatibility and communication of the elements of the system in a horizontal or vertical way, self-regulating components of the technical and manufacturing systems;

This way and this grouping define the methodological basis of the approach of studying the possibilities for adapting the requirements of Industry 4.0 in machine building companies, see fig.3.

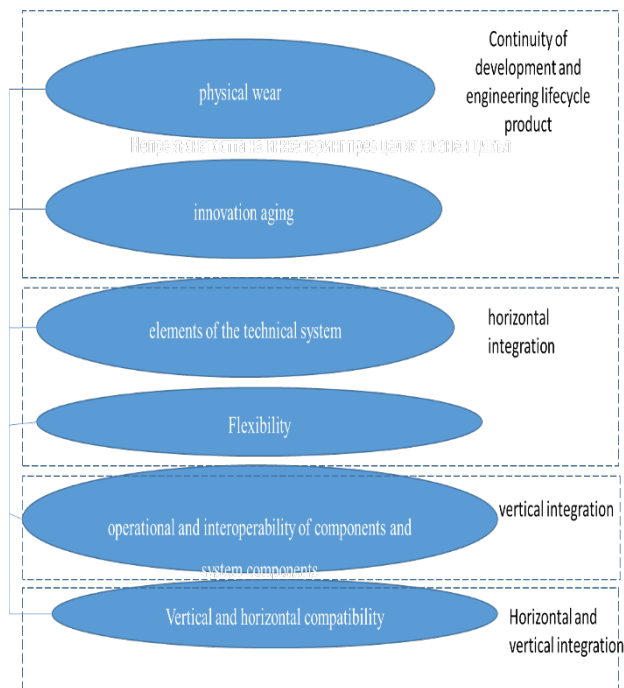


Fig.3 Factors for the Horizontal and vertical integration

The Innovative aging: is due to technology development and the speed of implementation of the innovations, physical wear is associated with machine parts without which the machine can not work.

Physical wear is a result of the constructive-technological and operational reasons. The development of new technologies is provoking innovation aging. A balance between the physical and innovational aging is necessary to be found.

Physical wear, can be considered in terms of changing the parameters of the equipment, without changing the productivity and with changing it (The change in physical condition of the details, machines, the quality, change in how it affects the environment, level of safety and so on.) or stopping work (cessation of operation).

The innovation aging is related with a delay due to technological reasons, for example: The appearance of a newer and more productive machine giving better quality of production.

The parameters and indicators that can characterize the conditions are:

Economically expressed in economic indicators: such as Operating costs, share of equipment per one unit of product, unit cost, depreciation costs.

Technical and technological parameters, expressed in technical parameters including operating life, reliability, efficiency, technological capabilities and more.

For the purpose of the study it is necessary to study the level of elements of the technical system in the enterprises: conventional type machines, machines with 2D control devices, machines with 3D control devices, automation devices (automation degree), automatic complexes (automation degree), self-regulating systems, technical compatibility (degree/level of elements in the system) and base and bonding models.

Degree of modularity through modular network, complex network and system network.

When creating a product, who is to be given to the costumer, there has to be a wide variety of options, as well as a big flexibility of the production capacities. The use if a “CPS” in the production process gives an opportunity for the firms to develop the different stages on a modular principal, as a result of that all the separate modules can be organized flexible and on their own. Thru a modular system, companies can make considerable savings in regards of the assembly and exploitation, but in the same time can offer optimal functionality when installing and maintaining the equipment. Often the importance of the full (or almost full) integration is underestimated and a decision is made for the purchase of software from different providers and also their assembly. This is when

problems begin to show, the data exchange is not complete etc. Such an assembly of individual modules is only possible under certain conditions, such as unifies connection margins, implementation of certain geometric and constructive constrains, observance of certain conditions for a previously build system of block modules.

Regarding the flexibility of a system, it is represented by the degree of adaptation to different models, possibility of change regarding the needs of the costumer, system adequacy to the changing requirements (replacement, expansion and so on.)

Regarding the degree of automation of the elements and components of the system (CAD/CAM/CAE), vertical and horizontal diversification, software (models) etc.:

Regarding the operational and functional compatibility of the elements and components of the system as a decentralization and transfer of information in real time.

Regarding the horizontal and vertical compatibility of the system, as technological and business operations in a vertical state, network models targeted for compatibility and communications of the elements is the system in a horizontal and vertical state. Self-regulating components of the technical and manufacturing system.

The challenges of the cyber-physical systems include:

Reducing complexity in the development of the stabilizing architecture of management for the cyber-physical systems:

Distributed sensor networks;

Conclusion

- A systematization was made of the factors, regarding the horizontal and vertical integration.

- The functions if the cyber-physical systems was analyzed.real-time information, flexibility, interoperability, modularity, decentralization and virtualization.

References

As a result of the shown above, the following conclusions can be made:

- The key element of the fourth industrial revolution are the cyber-physical systems, through which networks are created for the self-regulation of allocated production recourses.

- Introducing the principals of “Industry4.0” in the manufacturing requires the creation of an environment for its normal functionality. This means that the horizontal and vertical co-operation between machine and internet, machine - person and machine – machine on the chain of value in real time. This is the basis of the cyber-physical production system.

Literature

- [1] Scheer A. (2013) Industrie 4.0: Wie sehen Produktionsprozesse im Jahr 2020 aus?
- [2]. Bauernhansl, Thomas. Industrie 4.0 in Produktion, Automatisierung und Logistik. Anwendung, Technologien und Migration. Wiesbaden: Springer Vieweg, 2014
- [3] Plattform Industrie 4.0 2014: Industrie 4.0: Whitepaper FuE-Themen, http://www.plattform-i40.de/sites/default/files/Whitepaper_Forschung%20Stand%203.%20April%202014_0.pdf (12.3.2015).
- [4] Promotorengruppe Kommunikation der Forschungsunion Wirtschaft – Wissenschaft. Deutschlands Zukunft als Produktionsstandort sichern. Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0. Abschlussbericht des Arbeitskreises Industrie 4.0., 2013
- [5.]Nikolowa, I. Upravljenie na kachestvoto, King, 2016
- [6.]Roth, A. Einfuehrung um Umsetzung von Industrie 4.0, Springer,2016

MATHEMATICAL MODELING OF ENERGY INTEGRATED ATAD SYSTEM FOR THEIR SUSTAINABILITY IMPROVEMENT

МАТЕМАТИЧНО МОДЕЛИРАНЕ НА ЕНЕРГИЙНО ИНТЕГРИРАНА АТАД СИСТЕМА ЗА ПОДОБРЯВАНЕ НА НЕЙНАТА УСТОЙЧИВОСТ

Prof. Dr. Vaklieva-Bancheva N. G., Assist. Prof. Dr. Vladova R. K., Assist. Prof. Dr. Kirilova E. G.

Institute of Chemical Engineering at Bulgarian Academy of Sciences,
Sofia, Bulgaria

vaklieva@bas.bg, raika_vladova@abv.bg, eshopova@gmail.com

Abstract: *Autothermal Thermophilic Aerobic Digestion (ATAD) is a technology for municipal waste water treatment where Class A Biosolids is produced. ATAD systems characteristic with the simplicity of the process, the higher reaction rate and smaller bioreactors. Systematic observations carried out on conventional ATAD systems have shown that their major disadvantage is the thermal shock that occurs in first bioreactors stages due to uncertainties regarding to the quantities, composition and temperatures of the incoming into the system raw sludge. This study focuses on opportunities for the thermal shock reduction in conventional ATAD system through recovery the heat from the effluent stream. It can lead to substantial savings of the time required for operating temperature recovery and quicker bio-degradation. To reduce the impact of the stochastic parameters and to ensure efficient using of the waste heat for the sustainable operation of the ATAD system, two mathematical models of energy integration with one and two heat storage tanks are proposed which will be suitable to be involved in a stochastic optimization framework.*

Keywords: MODELING, ENERGY INTEGRATION, HEAT STORAGE TANKS, ATAD WWTP, UNCERTAINTIES

1. Introduction

Autothermal Thermophilic Aerobic Digestion (ATAD) is a novel technology for wastewater treatment. It uses aerobic microorganisms with exothermic energy metabolism. Conventional ATAD processes (Fig. 1) take place in parallel series of two batch bioreactors where the wastewater is treated at different temperatures with aeration and mixing for 20-24 hours.



Fig. 1. Conventional ATAD system (source Fuchs Gas- und Wassertechnik GmbH web page)

Once per day part of the treated sludge from the last bioreactors is discharged to “a product” storage. Then the partially treated wastewater from the previous stage is displaced to the next one and the system is fed with the fresh sludge from the feed tank. The required operational temperature for the bioreactors from the first stage is around 55°C, which is optimal for bacterial growth, while for the second one it is ~65°C – which is the best one for pasteurization.

The process of biochemical oxidation of organic substance results in releasing of energy in the form of heat, water, carbon dioxide, ammonia and etc. Heat retention within the system leads to increasing the operating temperature and increasing the rate of degradation of volatile organic as well as killing the pathogenic

microorganisms. ATAD systems benefit by the simplicity of the process, a higher reaction rate and consequently smaller bioreactors. Main problems in ATAD facilities arise during loading each new portion of raw sludge which leads to a sharp decline in temperature in the first stage bioreactors. The latter provokes a thermal shock (TSk) on the thermophilic microorganisms resulting in a decrease in the operating temperatures in the first bioreactor and often in the second bioreactor stage; prolongs treatment process and increases energy consumption for mixing and aeration. Depth of the thermal shock depends on variety of parameters that are subjected to daily uncertainties such as the volumes and temperatures of loaded raw sludge, ambient temperature, sludge properties etc. Due to the thermal shock the reactors from the first stage usually operate at about and below 50°C.

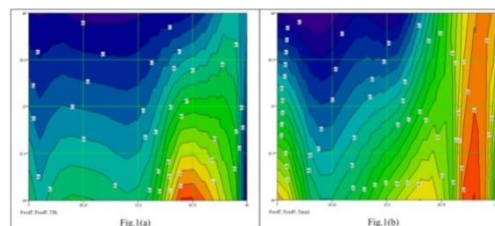


Fig. 2. Depth of the TSk (2a) and maximal temperatures achieved at the end of the process (2b) in bioreactors from the first stage depending on the temperature and quantity of loaded fresh sludge.

Reduction of the temperature drop in the first bioreactor and its impact on the microorganisms can improve the energy efficiency of ATAD systems and lead to more sustainable operating temperatures in the bioreactors. Having in mind that heat production and its retention into the system have a great importance for the ATAD process many researchers have analyzed the possibilities for energy efficiency improvement of ATAD systems.

Firstly, Layden et al. have found that re-using the heat released with outgoing from the ATAD system end product can reduce the fluctuations of the operating temperatures in the first bioreactors stages [1]. Based on this idea, Zhelev et al. have proved that this heat has a sufficient energy potential which can be used for preheating the raw sludge [2], [3]. It was proved that substantial

quantity of low grade heat at the exit of the second-stage bioreactors, under certain conditions could be used for preheating the fresh sludge supplied to the first one. Recovery and utilisation of this heat is obstructed by the fact that the system operates in a batch mode and the streams candidates for heat integration are shifted in time.

The aim of this study is development of an approach for the thermal shock reduction in conventional ATAD system. To ensure efficient using of the waste heat for the sustainable operation of the ATAD system, two mathematical models of energy integration with one and two heat storage tanks are proposed which will be suitable to be involved in a stochastic optimization framework.

2. Mathematical description of the process of energy integration of streams in the ATAD system with one heat storage tank

In 1993, Ivanov et al. [4] have proposed a method for heat integration of the flows outgoing in different time intervals from two, hot and cold, batch reactors by using one heat storage tank. We have implemented this method in the conventional two-stage ATAD system with two series (A and B) of bioreactors. The heat integration framework is shown in Fig. 3, [4]. Its general purpose is to integrate hot flows that appear during partial discharge of hot stabilized and pasteurized sludge from the second stage bioreactors - 2-A or 2-B, with the cold ones, appearing during loading of the raw sludge to the first stage bioreactors, 1-A or 1-B. Service, (loading and discharging) of each series is independent of each other.

The proposed heat integration scheme comprises two heat exchangers: *HE-c* for preheating the cold sludge, incoming from the feed tank toward 1-A or 1-B, and *HE-h* – for cooling the hot stabilized sludge discharged from the bioreactors 2-A or 2-B and as well as one heat storage tank. Intermediate fluid storing in the heat storage tank plays the role of heating or cooling agent at different time intervals. During loading the bioreactors 1-A or 1-B, the intermediate fluid stored as a hot agent in the heat storage tank, passes through *HE-c*, preheats the cold sludge, cools and returns back to it. Due to mixing the hot and cold intermediate fluids in the storage tank, the heat exchange in both *HE-c*, and the heat storage tank, is unsteady state. Accordingly, during discharging 2-A or 2-B, the cooled intermediate fluid, which is already placed into the heat storage tank, is used in *HE-h* for cooling the hot stabilized sludge, outgoing from the bioreactors 2-A or 2-B. This process is also unsteady state. Two sludge pumps transport the flows from the feed tank and bioreactors 2-A or 2-B toward corresponding heat exchangers, while the transport of heating/cooling intermediate fluid from the heat storage tank toward corresponding heat exchangers is carried out by one regular pump.

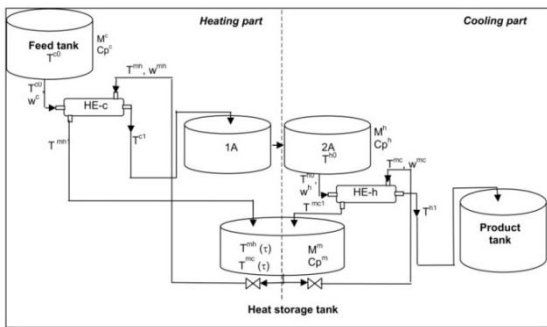


Fig. 3. Heat integration framework of batch ATAD system using one heat storage.

Mathematical model of the proposed scheme includes the following equations:

$$(1) \quad T^{c1}(\tau^c) = T^{c0} + [T^{mh}(\tau^c) - T^{c0}] R^c \Phi e^c,$$

$$(2) \quad T^{mh1}(\tau^c) = T^{mh}(\tau^c) - [T^{mh}(\tau^c) - T^{c0}] \Phi e^c,$$

$$(3) \quad T^{mh}(\tau^c) = T^{c0} + (T^{mh0} - T^{c0}) \exp(-G^{mh} \Phi e^c \tau^c),$$

$$(4) \quad T^{h1}(\tau^h) = T^{h0} - (T^{h0} - T^{mc}(\tau^h)) \Phi e^h,$$

$$(5) \quad T^{mc1}(\tau^h) = T^{mc}(\tau^h) + (T^{h0} - T^{mc}(\tau^h)) R^h \Phi e^h,$$

$$(6) \quad T^{mc}(\tau^h) = T^{h0} + (T^{mc0} - T^{h0}) \exp(-R^h \Phi e^h G^{mc} \tau^h)$$

(1-6) determine the temperatures of the inputs and outputs of the respective heat exchangers at the end of the energy integration of the streams in the ATAD system as well as the equations

$$(7) \quad T^{mh0} = \frac{b^{22} + b^{12} b^{21}}{1 - b^{11} b^{21}}; \quad T^{mc0} = \frac{b^{12} - b^{11} b^{22}}{1 - b^{11} b^{21}}$$

to determine the initial temperatures in the heat storage tank at which it began to play the role of “hot” or “cold” respectively. The model is supplemented with constraints providing the feasibility of the heat exchange in the heat exchangers:

$$(8) \quad \Delta T^c \geq \Delta T^{\min}$$

$$(9) \quad \Delta T^h \geq \Delta T^{\min},$$

where ΔT^c and ΔT^h are minimal temperature differences at the end of heat integration process for heat exchangers *HE-c* and *HE-h*. The temperatures values obtained by the model allow to determine ΔT^c and ΔT^h . There are equal to the smaller temperature difference at the end of the heat exchangers:

$$(10) \quad \Delta T^c = \min \left\{ (T^{mh1}(\tau^c) - T^{c0}), (T^{mh}(\tau^c) - T^{c1}(\tau^c)) \right\}$$

$$(11) \quad \Delta T^h = \min \left\{ (T^{h0} - T^{mc1}(\tau^h)), (T^{h1}(\tau^h) - T^{mc}(\tau^h)) \right\}$$

3. Mathematical modeling of heat integrated ATAD system with one intermediate heating/cooling fluid and two heat storage tanks.

The proposed model of heat integrated ATAD system consists of a common intermediate heating/cooling fluid and two heat storage tanks, called “*H-Storage*” for heat and “*C-Storage*” for cold and two heat exchangers *HE-c* to heat cold fluid and *HE-h* to cool hot one, Fig. 4 [5].

At the beginning of the integration process, before loading the bioreactor 1-A(B), the cold sludge income into the heat exchanger *HE-c* with initial temperature T^{c0} [°C]. It is heated counter-currently by the intermediate fluid coming from “*H-Storage*” tank, with an initial temperature T_m^{h0} [°C] and leaves the heat exchanger with temperature T^{c1} [°C]. After heat exchange the cooled intermediate fluid goes in the “*C-Storage*”. At the end of the integration process τ_c [h] the temperature in the cold storage tank becomes T_m^{c0} [°C]. Likewise, the hot “product” with an initial temperature T^{h1} [°C] passes through the heat exchanger *HE-h* and it is cooled by the intermediate fluid coming from the “*C-Storage*”, with an initial temperature T_m^{c0} [°C]. Then the cooled “end product” leaves *HE-h* with final temperature T^{h1} [°C]. The intermediate fluid

is stored in “H-Storage” and at the end of the integration process τ_h [h] the temperature in the hot storage is T_m^{h0} [°C].

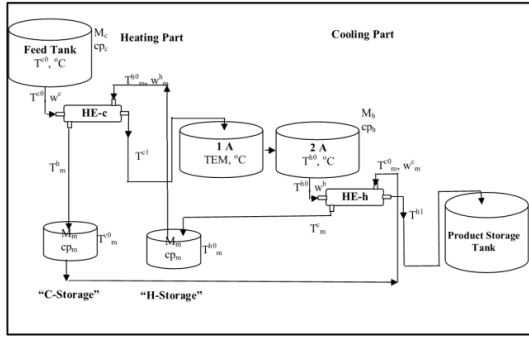


Fig. 4. Heat integration framework using two heat storage tanks.

Determination of the temperatures at inputs and outputs of both heat exchangers at the end on the integration process τ_c and τ_h is represented by the following equations:

$$(13) \quad T^{c1} = T^{c0} + (T_m^{h0} - T^{c0}) R^c \Phi e^c,$$

$$(14) \quad T_m^h = T_m^{h0} - (T^{h0} - T_m^{c0}) \Phi e^c,$$

$$(15) \quad T^{h1} = T^{h0} - (T^{h0} - T_m^{c0}) \Phi e^h,$$

$$(16) \quad T_m^c = T_m^{c0} + (T^{h0} - T_m^{c0}) R^h \Phi e^h.$$

where T_m^h [°C] is the final temperature of cooled hot intermediate fluid in HE-c;

T^{h1} [°C] and T_m^c [°C] are the final temperatures of cooled “end” product and heated intermediate fluid in HE-h.

The terms used in equations (13) and (14) are following:

$$R^c = \frac{w_m^h c p_m}{w_c c p_c}; \quad w_c = \frac{M_c}{\tau_c}; \quad w_m^h = \frac{M_m}{\tau_c} \text{ [kg/s];}$$

$$\Phi e^c = \frac{1 - \exp(-y_c U_c A_c)}{1 - R^c \exp(-y_c U_c A_c)};$$

$$y_c = \frac{1}{w_m^h c p_m} - \frac{1}{w_c c p_c}$$

M_c and M_h are the masses of the cold sludge and hot “end” product”, M_m is the mass of the intermediate fluid in [kg] and A_c and A_h are the heat exchanger areas of HE-c and HE-h in [m²]. The initial temperatures T_m^{h0} [°C] and T_m^{c0} [°C] in the “hot” and “cold” heat storage tanks calculate as follows:

$$(17) \quad R_m^{h0} = \frac{\Phi e^c (R^h \Phi e^h - 1) T^{c0} - R^h \Phi e^h T^{h0}}{(R^h \Phi e^h - 1)(\Phi e^c - 1) - 1}$$

$$(18) \quad T_m^{c0} = \frac{(\Phi e^c - 1) R^h \Phi e^h T^{h0} - \Phi e^c T^{c0}}{(R^h \Phi e^h - 1)(\Phi e^c - 1) - 1}$$

Thus, at given integration times τ_c and τ_h [h] initial temperatures T_m^{h0} and T_m^{c0} [°C] and the values of A_c , M_c , A_h , M_m , the temperatures at the inputs and outputs of both heat exchangers can be exactly calculated using the model (13)-(18).

4. Conclusions

The study deals with the problems of energy efficiency and sustainability improvement of the ATAD system for municipal wastewater treatment operating under uncertainties. For that purpose two mathematical models of heat integrated ATAD system with one heat storage tank and two heat storage tanks are presented.

Acknowledgement:

The study has been carried out by the financial support of National Science Fund, Ministry of Education and Science of the Republic of Bulgaria, Contract № ДН07-14/15.12.16.

References

- [1] Layden, N.M., (2007). *An Evolution of Autothermal Thermophilic Aerobic Digestion (ATAD) of Municipal Sludge in Ireland*, J. Environ. Eng. Sci., 6(1), 2007, pp. 19-29.
- [2] Zhelev, T., Vaklieva-Bancheva, N., Jamniczky-Kaszás, D., (2008). *About Energy Efficiency Improvement of Autothermal Thermophilic Aerobic Digestion Processes*, Comput. Aided Chem. Eng., 25, 2008, pp. 1-6.
- [3] Zhelev, T., Vaklieva-Bancheva, N., Rojas-Hernandes, J., Pembroke, T., (2009). “Smelly” Pinch, *Proceedings of the 10th International Symposium on Process Systems Engineering: Part A*. Comput. Aided Chem. Eng., 27, 2009, pp. 933-938.
- [4] B. Ivanov, K. Peneva, N. Bancheva, *Heat Integration in Batch Reactors Operating in Different Time Intervals. Part II. A Hot-Cold Reactor Systems with a Common Storage Tank*, *Hungarian Journal of Industrial Chemistry*, Volume 21, 1993, pp. 209-216.
- [5] Gomez, J., de Gracia, M., Ayesa, E., Garcia-Heras, J. L. *Mathematical Modeling of Autothermal Thermophilic Aerobic Digesters*, Wat. Res., 41(5), 2007, pp. 959-968.

IMPROVING THE PRECISION OF PLANT RESPONSE BY MODELING THE STEADY STATE ERROR

MSc. Dushko Stavrov, Assist. Prof Goran Stojanovski, Prof. DSc Stojche Deskovski,

Faculty of Electrical Engineering and Information Technology – University of Ss Cyril and Methodius in Skopje, Republic of Macedonia

dushko.stavrov@feit.ukim.edu.com.mk

Abstract: Nowadays, one of the most common problems in control system theory that should be tackled is how to improve the precision of a plant in steady state, under a change in the target value of the plant. Well known fact is that the models we use for designing controllers are not ideal. Thus, when the controller is applied to the real plant there is difference in between the expected and obtained results. Likewise, the controllers should be designed to be at the same time robust to uncertainties and also fast enough to drive the system to the desired value. The purpose of this paper is to describe and finally implement the approach in which the idea is to improve the precision of the system in steady state by adding an additive term to the control value calculated by the predesigned PID controller. The PID controller is designed in advance, and has poorly tuned integral term. Afterwards, when the desired target value is changed the PID controller is not aware of that change, so its performance starts to drop and as a result the steady state error starts to increase. Therefore, to preserve the exactness of the plant's output an additive term to the control signal is calculated out of a polynomial second order model derived from the error values obtained in the previous measurements of the plant. The results from MATLAB simulations have shown that the PID controller could not keep up good performance when the target value of the system is changed. Hence, by adding an additive term to the control signal we gave to PID the needed 'awareness' and as a result of that we could improve the steady state error by small margin.

KEYWORDS: PID CONTROLLER, ADDITIVE TERM, POLYNOMIAL SECOND ORDER, EXACTNESS,

1. Introduction

In control literature, one can easily find a variety of different examples for industrial control, where contemporary control algorithms are implemented. Surprisingly, there are not much known examples where the state-of-art control algorithms have been implemented in real-time control systems, like for example: missiles, jets, drones, robots, etc. Instead as control techniques for such systems researchers usually implement algorithms that are proven to be reliable, fast and easy to implement. In the light of this discussion we can add that nowadays control algorithms are not a single or stand-alone solution, like the basic PID controller is. Instead contemporary controllers are supported by a bundle of additional procedures. For example, the MPC algorithm ([6], [7]) which is considered as main candidate to replace the much simpler, wholly grail of industrial control - the PID controller, uses a lot of background computations to generate the control signal.

The PID controller is in the heart of control engineering practice for more than seven decades. The PID controller is one of the most commonly used controllers in industry. Some of the reports show that PID controllers are being used in 90-95% of the control loops in industry ([1], [2]). Its simple structure has made PID controller one of the most widespread controllers in all technical systems. Over the long history of its use and development, the simple notation of PID control mechanism has been augmented with new features that aim to improve its efficiency. However, the key question that many scientists try to solve is - which is the best procedure to tune the PID parameters, in order to achieve the desired control object performance. One should mention that one of the most broadly used method of computing the PID coefficients, in industry, is Ziegler Nichols method ([3]). However, we should make a notice of a reference of the tuning of PI and PID controllers ([4], [5]) whose second edition published in 2006, shows that there are more than 400 versatile methods of PID synthesis. Even though there are a lot of synthesis methods of PID controller, some reports say that around 80% of the PID controllers are poorly tuned, where 30% of the the PID controllers operate in manual mode [9].

Although there are a lot of advantages of PID control, it cannot be successfully used when dealing with system with drifting parameters. It is well known that the industrial plants, are subject to change in time and the possibility of parameter drift in the plant drastically increases as the plant is being operated. We interpret this as parameter uncertainties in the control object which usually leads to worse performance of the control system. Hence, if the PID

controller was initially designed to work for a particular operating point, after the parameters drift, the controller should be adapted to the new operating conditions. If there is not some kind of supervisory system that automatically takes care of the adaptation, we should track the parameter drift and occasionally tune the PID parameters.

The above mentioned problem of parameters drift can be solved with adaptive control algorithms, which are making continuous or periodic corrections in the PID coefficients [12]. The problem that arises in this situation is the speed of adaptation of the coefficients. Surely, we want to reduce the time of adaptation to the possible minimum.

Nevertheless, there are other possibilities for correction of the effects derived from the parameter drift. In this paper, we assume that the parameters are already obtained using trial and error. Therefore, we propose an improvement to PID controller in form of an additive term to the PID control value, as $u_{PID} + \Delta u$, aiming to improve the precision of the control object in the steady state. This is of great importance in control systems in chemical industry and manufacturing plants, where the precision in steady state is of great concern for safety and as well as for cost effectiveness.

Moreover, the additive term is calculated as a root of the quadratic polynomial model which is modelled out of the set of previously stored values of the steady state error and additive term values. In mathematical terms the error model is given by:

$$E_M = f(\Delta u). \quad (1)$$

The rest of the paper is structured as follows. Firstly, the mathematical background of the simple and enhanced PID is presented; then the PID enhancement is discussed in more details. Secondly, the case study of a CSTR control system is modelled. Afterwards, both PIDs are applied to the CSTR system and the obtained results are analyzed. Finally, conclusions and outlook for future work are given.

2. Mathematical formulation of simple PID and enhanced PID

Simple PID formulation

Despite the simplicity of the basic notion of a PID controller, we can distinguish several different forms of implementation of a PID control law. Likewise, in industry various forms of PID

controllers are used, more than ten in whole. For more information about different forms of PID realizations see references ([4], [5]).

In this paper we have focused on the simplest PID realization and that is the parallel form. The control signal with this PID form is generated by the following equation:

$$u_{PID}(t) = u_0 + K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}. \quad (2)$$

Where, u_0 is a bias in the control signal and $e(t) = SP - PV$ is the current error, which is calculated as difference between set point (SP) also known as reference value and the process value (PV). The coefficients of the PID are, K_p - the proportional term, K_i - the integral term and finally K_d is the derivative term. By any means the generation of the control signal is done very fast and the control value only depends on the current as well as the past values on the error. On Figure 1, the control loop consisted of PID controller and control object is shown.

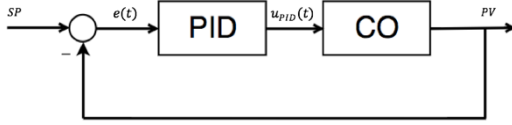


Figure 1 PID control loop.

Enhanced PID formulation

As we mentioned before, in the introduction, the simple PID controller doesn't have awareness of how good its parameters had been tuned. Accordingly, in this paper we have tried to give the needed awareness to the PID with the objective to deal with error in steady state as well as to improve the time needed to get in steady state. The principle schematic representation of the approach is given on the Figure 2.

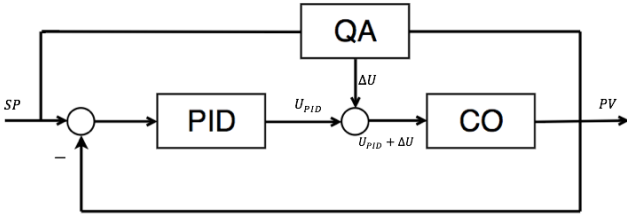


Figure 2 PID control loop.

On Figure 2 the change we have done on the simple PID structure is shown. As opposed to what is on the Figure 1 we can see that on Figure 2 there is an additional component named QA. It is an abbreviation of the word Quadratic Approximation. The main idea is, as the control system operates, in the background to have some kind of supervisory mechanism which principle purpose would be to model the steady state error in the system. Afterwards the same model presented with equation (1) will be exploited as apparatus out of which the additive term Δu will be calculated.

The whole process of plant control, calculation of the PID control value in addition to additive term is given with the flow chart on Figure 3. Where N_s is the number of simulation steps of the plant (control object). As long as the counter $i \leq N_s$ the plant is controlled in as presented on Figure 2. When the condition given with equation, (3) is true, the steady state error defined with the equation (4) is calculated and stored. The name, mod stands for function which gives information whether in division between i and DV there is residuum or not. If the residuum is zero that means that i is divisible with the number DV . The index j in the brackets, in (4), indicates how many times the condition given with (3), was fulfilled and in the same time, it gives the number of collected steady state error points which after that will be used for designing a quadratic model, equation (1). The variable PV_{ss} stands for steady state value of the process value. Further, DV stands for the

Dynamical Variable, which defines on how many simulation steps an error point should be collected.

$$\text{mod}(i, DV) = 0, \quad (3)$$

$$E_{ss}(j) = SP - PV_{ss} \quad (4)$$

The next step is to check whether $j \geq 6$, if it is not, then a simple metric is used for producing the points needed for quadratic model fitting.

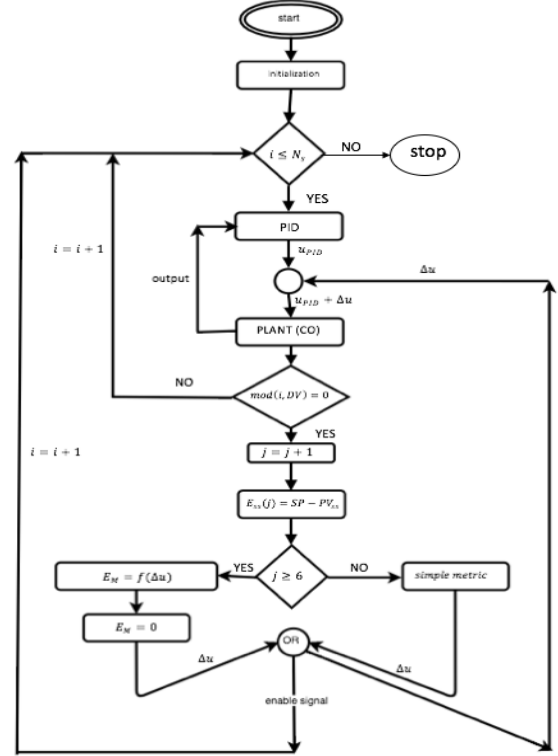


Figure 3 Flow chart diagram of proposed algorithm.

The metric that has been used is,

$$\Delta u = k_{ss} \sum_{m=1}^j E_{ss}(m). \quad (5)$$

where the parameter k_{ss} is obtained using the trial and error method. Afterwards, when 6 points are gathered, it is easy to fit a quadratic model like the one given with (6). To fit the model (6) we only need 3 points ([10], [11]). In other words, the sufficient number of points is equal to the number of unknown parameters. In this paper the model was dynamically generated out of the last 6 steady state error points. The equation of the model is given by:

$$E_M(\Delta u) = A(\Delta u)^2 + B(\Delta u) + C \quad (6)$$

The parameters A, B and C of the model are calculated by solving the next equation:

$$p = (M^T M)^{-1} M^{-1} \cdot J \quad (7)$$

Where $p \in \mathbb{R}^3$ is a vector of parameters,

$$p = [A, B, C]^T, \quad (8)$$

$M \in \mathbb{R}^{6 \times 3}$ is a matrix of 6 points, which are considered to determine the parameters p .

$$M = \begin{bmatrix} (\Delta u_1)^2 & \Delta u_1 & 1 \\ \vdots & \vdots & \vdots \\ (\Delta u_6)^2 & \Delta u_6 & 1 \end{bmatrix} \quad (9)$$

At last, $J \in \mathbb{R}^6$ denotes the vector of error values. Equation (7) can be solved if the inverse $(M^T M)^{-1}$ exists, which means that the matrix M should have rank equal to the number of parameters, in

our case that number is 3. In other words, the points used for regression have to be distributed in a way that the rank of matrix M is not smaller than 3.

At first sight, 3 points seem to be enough to solve the equation (7). However, there are cases in which the chosen 3 points are not suitable. First of all, it is clear that two points should not be placed in the same location which leads to a reduced rank of M . Furthermore, it has to be ensured that the points are not distributed on a line. Anyway, if that is the case then the information provided by the points is not adequate to describe a quadratic function exactly.

3. Case Study: Nonlinear Non-isothermal Continuous Stirred Tank Reactor

Consider a simple liquid-phase, irreversible chemical reaction where chemical reactant A is converted to product B. The reaction that happens in the reactor can be written as follow $A \rightarrow B$. Also, we assume that the rate of reaction is first-order with respect to reactant A:

$$r = kC_A \quad (10)$$

where r is the rate of reaction of A per unit volume, k is the reaction rate constant and C_A is the molar concentration of reactant A. For a single-phase reaction as we are assuming here, the rate constant is typically a strong function of reaction temperature. The rate constant is given with the equation:

$$k = k_0 e^{-\frac{E}{RT}} \quad (11)$$

where E is the activation energy, R is the gas constant and k_0 is the frequency factor.

The graphical representation of the CSTR is given on Figure 4. The input in the system is the inlet flow which is consisted of reactant A with concentration C_A . Often, the reactions happening in CSTR system have significant heat effects. Thus it is important to be able to add or remove heat from them. Adding or removing heat from reactor depends on the temperature difference between the cooling jacket fluid and the reactor fluid.

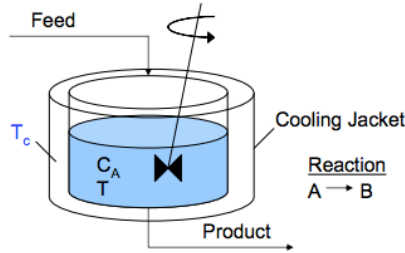


Figure 4 CSTR system.

The model of this control system is given by the following two equations [8]:

$$\frac{dT}{dt} = \frac{q}{V}(T_f - T) + \frac{\Delta H}{\rho C_p} k_0 e^{-\frac{E}{RT}} + \frac{UA}{V\rho C_p}(T_c - T) \quad (12)$$

$$\frac{dC_A}{dt} = \frac{q}{V}(C_{Af} - C_A) - k_0 C_A e^{-\frac{E}{RT}} \quad (13)$$

where T_c , the temperature of the cooling jacket fluid, is the manipulated variable and T , reactor temperature, is the controlled variable. Production of the desired component concentration depends on coolant flow rate, reactor temperature and reaction rate. It is assumed here that the cooling jacket flow is fixed. Other parameters values contained in equations (12) and (13) are given in Table 2.

For the purpose of simulating and also solving the equations (12) and (13) MATLAB has been used. More precisely for numerically solving of system equations the ode23t function was

employed with integration step of $T = 0.01$ min. The initial conditions of the system are given in the Table 1.

Table 1: Initial conditions for temperature and concentration

$T(0)$	296.6 K
$C_A(0)$	0.98 mol/m ³

Table 2: Model parameters.

Parameter	Value	Parameter	Value
Volumetric flowrate [m ³ /sec]	$q = 100$	Overall heat transfer coefficient [W/(m ² K)]	$UA = 5 \cdot 10^4$
Volume of CSTR [m ³]	$V = 100$	Feed concentration [mol/m ³]	$C_{Af} = 1$
Density of A-B mixture [kg/m ³]	$\rho = 1000$	Feed temperature [K]	$T_f = 350$
Heat capacity of mixture [J/(kgK)]	$C_p = 0.293$	Activation energy [J/mol]	$E/R = 8750$
Heat of reaction [J/mol]	$\Delta H = 5 \cdot 10^4$	Pre-exponential factor [1/s]	$k_0 = 7.2 \cdot 10^{10}$

4. Implementation of the discussed algorithms, PID and enhanced PID and results

In this part we will apply the two PIDs, discussed before, on the CSTR system. First of all, the parameters of both PIDs will be defined. Further, the two algorithms will be simulated in MATLAB, in the fashion given on Figure 1 and Figure 2, where the CO (Control Object) is the highly nonlinear system CSTR. To prove that, the CO is highly nonlinear, we have carried out an open loop simulation. The simulation of the algorithms was carried out over a period of 135 minutes or speaking in simulation steps $N_s = 1350$. The next, Figure 5 shows that at temperature of the 305 of T_c the CSTR system exhibits limit cycle behavior.

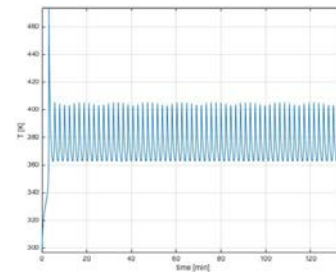


Figure 5 Open loop simulation of the CSTR system at coolant temperature of 305 K.

Furthermore, in this paper we assumed that all of the parameter in the system are constant and do not survive drift. Both controllers, simple PID and enhanced PID will be compared in two different scenarios. The first one (Scenario 1) is when the reference value (SP) changes from 300 to 305 K. The second one (Scenario 2) is when the reference value (SP) changes from 300 to 295 K. In both scenarios the responses of the PIDs will be compared. The IAE (Integral Absolute Error) metric given with the equation:

$$IAE = \frac{1}{N_s} \sum_{r=1}^{N_s} |e(r)|, \quad (14)$$

is used to estimate how well one of the controllers performs over the other. We should also mention that the parameters of the two controllers in both scenarios are the same and are given in Table 3,

Table 3: both PID parameters

K_p	4.5
K_i	0.5

Let's first consider the Scenario 1, when the SP changes from 300 to 305 K, at 60 minute. On the next figure (Figure 6) are given the responses of both PIDs, the response of the simple PID is given in blue whereas the response of the enhanced PID is given in red.

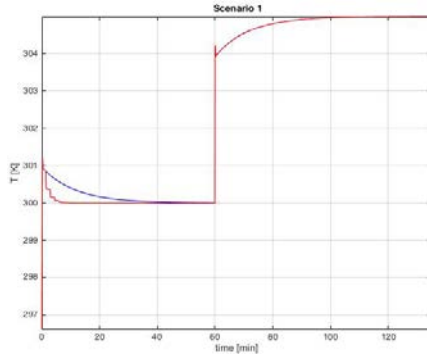


Figure 6 Response of the CSTR system in cases when it is controlled by simple PID (blue line) and enhanced PID (red line) in Scenario 1.

From the Figure 6 we can conclude that the overall response of the system has improved. Indication for that is the metric IAE, its values show that the enhanced PID is performing better than the simple PID. The IAE values, for Scenario 1, are given in the Table 4:

Table 4: IAE values for the Scenario 1

Simple PID	0.1801
Enhanced PID	0.1156

Let's now consider the Scenario 2, when the SP changes from 300 to 295 K, at 60 minute. On the next figure (Figure 7) are given the responses of both PIDs, the response of the simple PID is given in blue whereas the response of the enhanced PID is given in red.

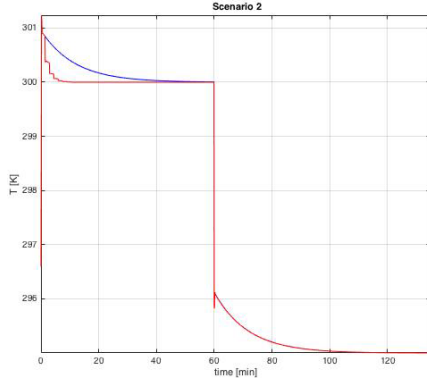


Figure 7 Response of the CSTR system in cases when it is controlled by simple PID (blue line) and enhanced PID (red line) in Scenario 2.

Figure 7 indicates that the enhanced PID controller in first phase of the simulation, until 60 minute, is able to converge very fast to the SP value, but after the 60 minute the enhanced PID and simple PID are performing equally bad. That was also the case in the first scenario. It is a problem that indicates that the quadratic model has not ability to adapt very well. A solution for this problem is already being considered; it is thought that the problem might be solved by adding additional information into the model, such as the temperature T or the SP value. However, the values of the IAE metric as in the Scenario 1 led us to the same conclusion in the Scenario 2. The enhanced PID performs better by small margin. The IAE values in Scenario 2 are given in the table that follows:

Table 5: IAE values for the Scenario 2

Simple PID	5.5467
Enhanced PID	5.4821

5. Conclusion and outlook for future work

In this paper we present an enhanced PID controller used to compensate for the steady state error. The presented controller is compared with a standard PID controller most commonly used in industry, with poorly tuned integral term. The proposed algorithm uses historical values for the steady state error and the additive control term to create a simple quadratic model of the plant's steady state error. The simulations have shown that the enhanced PID using the additive control term beats the performance of the simple PID by a small margin.

Future work will consist of implementing and afterwards comparing the same controllers presented here, in a case where they are used to control a system, possibly the same one CSTR system, which exhibits drift in some of the parameters. In such conditions, it is expected that the proposed control approach will have superior performances over the standard PID.

ACKNOWLEDGEMENTS

The work was funded by the Faculty of Electrical Engineering and Information Technologies in Skopje, Republic of Macedonia, through the ERESCOP Project.

REFERENCES

- [1] Astrom, K. J. and Hagglund, T., Advanced PID control, North Carolina: ISA, 2006.
- [2] Rotach, V.Ya, Teoriya avtomaticheskogo upravleniya: uchebnik dlya VUZov (Automated Control Theory: Univeristy Textbook), Moscow: MEI Publishing House, 2008.
- [3] Ziegler, J.G. and Nichols, N.B., Optimum Settings for automatic controllers, Trans. ASME, 1942 vol.64, pp 759-768.
- [4] O'Dwyer, A., Handbook of PI and PID controller Tuning Rules, London: Imperial College Press, 2009 3th ed.
- [5] O'Dwyer, A., Handbook of PI and PID controller Tuning Rules, London: Imperial College Press, 2006 2th ed.
- [6] Badwe, A. S., R. D. Gudi, R. S. Patwardhan, S. L. Shah, and S. C. Patwardhan, Detection of Model-Plant Mismatch in MPC applications, J. Process Control, 19, 1305 (2009)
- [7] Camacho, E. F., and C. Bordons, Model Predictive Control 2nd ed., Springer-Verlag, New York, 2003
- [8] D.E. Seborg, D. A. Mellichamp, T. F. Edgar, and F. J. Doyle III, Process dynamics and control: John Wiley & Sons, 2010.
- [9] P. Van Overschee and B. De Moor, in Preprints, Proc. PID '00: IFAC Workshop, Terrassa, Spain, pp. 687-692, 2000
- [10] G. Stojanovski, L. Maxeiner, S. Kramer, S. Engell, "Real-time Shared Resource Allocation by Price Coordination in an Integrated Petrochemical Site", 2015 European Control Conference (ECC), pp. 1492-1497, 2015.
- [11] S. Wenzel, R. Paulen, S. Kramer, B. Beisheim, S. Engell, "Shared Resource Allocation in an Integrated Petrochemical Site by Price-based Coordination Using Quadratic Approximation", 2016 European Control Conference (ECC), June 29 – July 1, 2016 Aalborg, Denmark.
- [12] Rania A. Fahmy, R. I. Badr, Farouk A. Rahman, "Adaptive PID Controller Using RLS for SISO Stable and Unstable systems", Advances in Power Electronics, Volume 2014, Article ID 507142.

REACHABILITY PLANNING OF INDUSTRIAL ROBOT IN CONCEPT OF DIGITAL FACTORY

doc. Ing. P. Košťál, PhD. & doc. Ing. Š. Václav, PhD. & Ing. D. Michal & Ing. Š. Lecký
Faculty of Materials Science and Technology in Trnava – Slovak University of Technology, the Slovak Republic
peter.kostal@stuba.sk, stefan.vaclav@stuba.sk, david.michal@stuba.sk, simon.lecky@stuba.sk

Abstract: *One of the factors that influence the production and assembly systems based on robotic cooperation is the reachability of the required locations as well as the design of the robotic arm paths without the need for initial testing at a real workplace, which could lead to damage of some parts in the workplace. The resulting robot paths must be collision-free, they cannot correlate with other elements of the automated workplace, they should also follow the set production cycle. The trajectory time described by the industrial robot end effector influences the overall production cycle time. For this reason, it is necessary to create a trajectory which represents the shortest path described by the industrial robot. The design of the end effector path of an industrial robot must in general meet many criteria, either in terms of tact or safety. By simulating multiple path trajectory variants in the digital environment, it is possible to select the ideal trajectory of motion of the industrial robot depending on the layout of individual elements of the production or assembly system and the elimination of collisions. When designing a robotic workstation, the main parameters of the industrial robot are range and load capacity. By implementing CAD data and customer requirements into the digital environment of the selected software, we can verify the data and choose the most appropriate solution. The main benefits of industrial robot application and the use of available software to efficiently design a robotic system include benefits such as shorter production times and associated higher productivity, labor cost savings and wage costs reduction, robots are used in other applications after the end of the production cycle of the original product, thereby achieving savings in investment costs.*

Keywords: TECNOMATIX, PROCESS SIMULATE, DIGITAL FACTORY, INDUSTRIAL ROBOT, WELD POINT,

1. Introduction

Nowadays, efforts are being made to shorten the cycle of products, to increase the usability of production systems and to reduce the complexity of products, requiring changes in the technical preparation of production as well as in the production process. The number of newly-developed and upgraded products in the industry is large and will be further enhanced by the improvement of technical solutions. A partial solution is the application of industrial robots to manufacturing or assembly systems.

Industrial robots are used in various industries such as welding, pressing, machining, painting, etc. Pressure to increase quality, productivity and cost reduction opens space for industrial robots, including machine handling and material handling. Industrial robots can move with high precision repeatability and trajectory of handling moves compared to conventional solutions, making cycle times shorter. The advantage is that the robot is not a dedicated device, for example, on machine operation, e. g. within the cycle time can do other additional operations in addition to the primary operation.

The main technical advantages of the industrial robot are undoubtedly the stability of the process and hence the achievement of high quality requirements for the final product, as well as the flexible production process change and the rapid incorporation of the technical change of the product. The major economic benefits include shortening production times and bringing together higher productivity, labor cost savings and lower wage costs, the ability to use robots in other applications after the end of the production cycle of the original product, and thereby achieve savings in investment costs. When designing a robotic workstation, the main parameters are the industrial robot, its range and load capacity.

Optimization of a robotic workstation can be analyzed from multiple angles, regardless of the area. Optimization can occur in:

- production,
- communication,
- management,
- logistics,
- ATC.

Optimizing these and other areas is geared to the main goal of increasing efficiency, saving costs, increasing productivity. Maintaining the right to maintain high quality and production stability is a matter of course. The possibility and scope of optimization of the robotic workplace is given by sufficient flexibility, which is achieved using appropriate technologies at the

very design of the workplace. Availability visualization is done in a 3D software environment where it is possible to determine the cycle time, the reachability of the industrial robot and at the same time to verify the functionality of the proposed workplace. With the increasing demands on the efficiency of production, its reliability and the quickest putting into operation are an important part of the design of the production and assembly lines, becomes a computer simulation.

Computer simulation enables virtual verification of plans and assembly lines before the start of production, helping to mitigate risks, whether cost or real-estate safety. It is a comprehensive tool that can verify the feasibility of the assembly process by controlling the reachability and eliminating possible collisions. This process is performed by simulating the whole assembly procedures of the product and the required tools and their interaction. Using computer simulation, it is possible to design the most optimal way of these processes and to incorporate all the necessary means necessary for the planned production process. The main advantages of computer simulations include the possibility of early detection of errors in the design and optimization phase of production, the possibility of making analyzes of the feasibility of a given solution or examining ergonomics of manual works.

2. Literature analysis

The effectiveness of robotization lies in the rapid integration of robots into production processes and, above all, in their economic and social benefits. Under economic benefits, we mean increasing labor productivity, stability and improving production quality, improving production management, and saving resources. In addition to the benefits that can be quantified to save production costs, the introduction of robots generates many secondary effects that only assist in deployment, such as lowering the technical preparation of production, reducing the need for operative production planning, and shortening production lead times.

2.1 Robotized workplaces

Robotic applications for Smart Manufacturing, whose definition and ideas constitute the current development trend in robotic systems, define new requirements for the technical level of in-use equipment. Innovating current solutions puts emphasis on the development of fully integrated and interoperable manufacturing systems that can respond in real time to conditions and requirements changing in real time. An integral part of the successful development of the Smart Manufacturing Application vision is industrial robots that provide the user with a high level of

functionality, flexibility and mobility. Their ability to collaborate safely in direct interaction with humans or other industrial robots, on the other hand, provide simple parameterization and definition of the tasks performed, which will allow the rapid and seamless integration of new devices into existing infrastructure within the production process. [4]

The geometry description aims at defining the movement of the end effector of the industrial robot over time and excluding force effects, determining its path, velocity and acceleration. The operation of the industrial robot consists in adjusting the discrete positions of the working head or in the continuous motion of the working head after a generally defined spatial trajectory, whereby the orientation of the working head is also controlled. Thus, the working head is a functional part which, depending on the nature of the desired activity, determines the use of the motion robot movement system. Due to the kinematic scheme of industrial robots and the scope of their workspace, emphasis is placed on the trajectory itself to eliminate the risk of interaction with the robot peripherals, and therefore emphasis is placed on workplace layout and ease of accessibility. [4]

2.2 Simulation software

Simulation software allows simulation of all activities from product design, assembly techniques, production planning, operational management, manufacturing of parts, inspection, assembly, packaging through to dispatch, in order to reduce material and energy consumption, increase productivity, reduce inventory, shorten the interim development and production times, increase time and power utilization of production facilities, and increase product quality. The potential of using simulation software is high. To select the software, you need to have a clear idea of the usability and suitability of the selected software, and it is necessary to correctly define the criteria and the objective of the project.

Issues and errors detected during simulation:

- large transport points,
- small storage capacity,
- Insufficient storage capacity,
- excess or shortage of workers,
- poor layout of workplaces,
- downtime.
- high caries,
- Insufficient maintenance,
- Unusable workplaces during breaks,
- Verification of functionality, reliability and performance,
- poorly planned progress of individual operations in the project.

There are models that are built for single use only (eg when analyzing processes to confirm the correctness of our hypotheses). Next are the models whose use is repeated. These are, therefore, simulation models of production and logistics systems that are still available to the user. Such models are used, for example, to verify the availability of system capacities, production plans, and the number of workers depending on the plan. An important part of the reuse of the model is its updating. The user not only changes the production plan but needs to constantly update the basic process data in the simulation model (e.g. machine failure, cycle times, sorting times). Today's simulation software can communicate with different databases or spreadsheet editors. Therefore, process data can be maintained in MS Excel spreadsheets or automatically downloaded from the enterprise information system. This greatly reduces the simulation model user's expertise. Although the construction of the model is performed by an expert, it can also be

used by a scheduler in the production, and may not be able to control the programming language. [3]

2.3 Tecnomatix Process Simulate

Process Simulate is one of the major modules for simulating manufacturing processes that helps minimize startup costs and change the production program. It enables the virtual verification of plans and assembly lines before the start of production, thus helping to mitigate risks, whether cost-related or in real-life safety. It is a comprehensive tool that can verify the feasibility of the production or assembly process and eliminate possible collisions. This process is carried out by simulating the entire assembly or production procedures of the product and the required tools and their interaction. Its task is to design the most optimal solution of the processes and to involve all the necessary means necessary for the planning of the production process. This module is fully integrated with the Teamcenter platform, allowing engineers and designers to reuse data that has been used in past designs and re-process, validate, edit, and use in the future. This archiving enables easy return to data, facilitates and accelerates the design of production systems and links. It also simplifies the simulation of human processes, mechanical processes, tools, devices and robots. Process Simulation creates complex and realistic views of the look and course of production through relatively detailed and credible simulations. [1, 2]

Process Simulation is the solution to minimize the risk of manufacturing change or the rise of new production lines. It will allow you to verify practically plans from the concept to the start of production to help mitigate these risks. The ability to use 3D data of products and resources, facilitates virtual verification, optimization and introduction of complex manufacturing processes, resulting in faster startups and higher production quality. Tecnomatix - Process Simulation can verify the feasibility of the assembly process by verifying availability and collisions. This is done by simulating the complete order of assembly of the product and its working tools. Tools such as cutting, measuring, and collision detection allow detailed control and optimization of production and assembly scenarios.

The main features include activities such as 2D and 3D view, 3D simulation, static and dynamic collision detection, 3D measurement, assembly planning, line design and workspace, filtering and displaying products and production information. There are advantages [2]:

- Reduce the risk of changing the production system,
- shortening planning time for new production systems,
- Reduce change costs with early error detection,
- Analysis of ergonomic processes,
- selecting the best option, by deducting several production alternatives [2]

When using the Tecnomatix - Process Simulate software correctly, the given robot simulation can be used as off-line programming and PLC code generation. The off-line industrial robot programming method offers several benefits, shortening the time of deployment of the robot, detecting collisions and detecting unrealizable and dangerous situations. The actual working range of the robot is known before the physical realization, which allows the selection of a suitable industrial robot. In addition to the advantages when introducing a new workstation, it is advisable to apply the off - line programming method to the process of changing the workplace, during which the delays occur during reprogramming of the robot during operation. [2, 5]

3. The example of Tecnomatix Process Simulate application

At first, we need to define what kind of research question we are going to solve by simulation.

Research question:

What are the limitations of the new proposed production system, and how can the production system be put into practice realistically and to what extent?

In the following example, we will introduce a digital model that defines a manufacturing system focused on spot welding process. A key element is the creation of a trajectory of an industrial robot with an end effector. This model is designed by Tecnomatix Process Simulate from SIEMENS.

To create the simulation of the digital model itself, it is necessary to define the correct kinematics of the CAD model of the industrial robot and scoring welding pliers.

The Process Simulate system distinguishes between passive items and those having joints enabling them to move; the latter are kinematic and are designated mechanisms. Mechanisms have links connected by axes to constitute joints. Links are hierarchically related to each other such that every link is either a parent link or a child link relative to another link, or both: an intermediate link may be a child link to one link and a parent link to another link. If the links of a mechanism are connected such that no link has more than one parent or more than one child, the mechanism is a chain. Every joint is either prismatic (linear) or rotational, and has limits of maximum and minimum movement (distance of travel), and maximum speed and acceleration. Every mechanism is either a device or a robot. If it has only links and joints, it is a device. If in addition it has a base frame and a tool frame, it is a robot. A robot also has a tool center-point frame (TCPF) which initially is superimposed on the tool frame, and a reference frame (REFRAME) to which the coordinates of all robot frames except the base frame are referenced. These frames are identified by names and have six numerical values expressing the X-Y-Z coordinates of position and the Rx-Ry-Rz coordinates of orientation; the Rx coordinate is a rotation around the X axis, the Ry coordinate is a rotation around the new Y axis, and the Rz coordinate is a rotation around the new Z axis. [6]

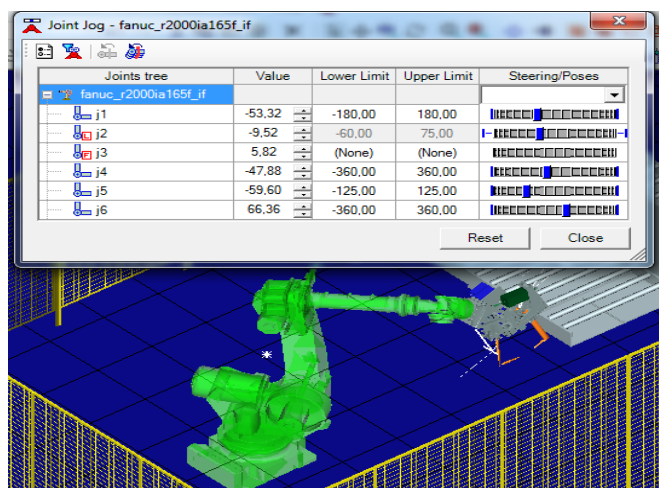


Fig. 1 Value of joint

When we have a CAD model of an end-effector industrial robot and a kinematics created, simulation can be created. In this example, New Weld Operation is used, which involves designing welded points. Subsequently, auxiliary points are created to guide the industrial robot with the welding point ticks to the desired location. To create the right trajectory and simulation, it is necessary to

identify the technological points and points. Technological points are specific places where the technological process takes place. In this case, it is spot welding. The welding point pliers are attached to the industrial robot arm. The auxiliary points serve to accurately guide the welding scoring pliers on the industrial robot arm to the point of the first welded point, through the intersections between the welded points and to leave the space after the welding operation is completed. These help points are important to correctly determine that no collision occurs because the robot automatically selects the shortest path when starting a process with the Home position to the point of the first welded point or when passing between the welded points.

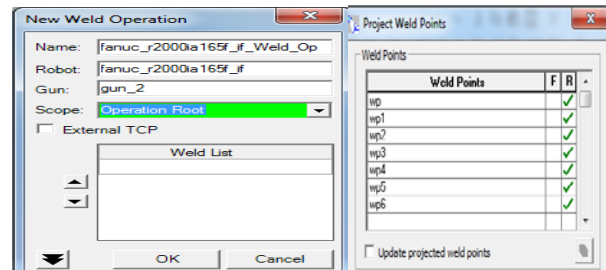


Fig.2 Project Weld Points

The next step for guiding welding scoring pliers mounted on the arm of the industrial robot is the orientation of the created technological and auxiliary points. It is necessary to set correct points orientation in the coordinate system with axes x, y, z to avoid collisions of the industrial robot with welding pliers with other objects in the vicinity. It sets the direction and angle of access of the industrial robot's tool (welding point pliers) to a predefined point, such as a technological or auxiliary access point.

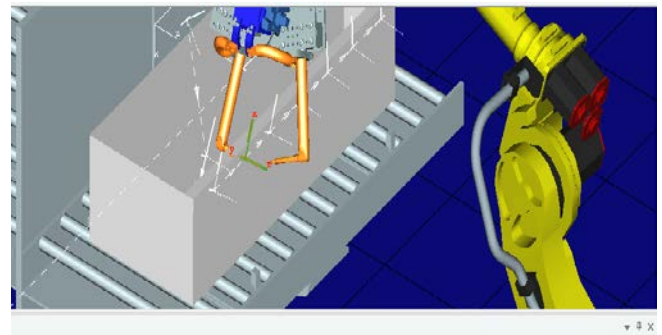


Fig.3 Trajectory of motion weld gun

After creating the trajectory of the industrial robot path with the end effector, adjusting the orientation of the technological and auxiliary points, and removing the collision states, it can create a simulation.

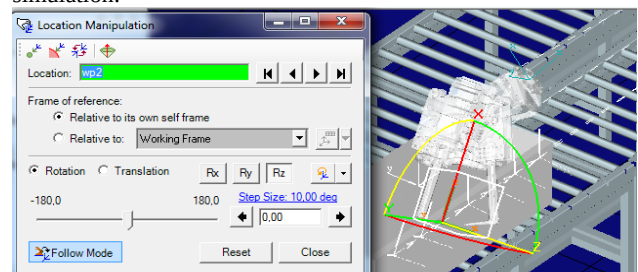


Fig.4 Location and orientation weld gun

In this part, it is possible to simulate a technological process with different speed parameters of the movement of an industrial robot where it is possible to observe the change of the time character of the technological process and eventually the collision. Before running the simulation, it is necessary to sort the operations

in the Operation Tree according to the time sequence. In the case of creating a simulation consisting of multiple operations, it is possible to create groups and subgroups that will include individual operations.

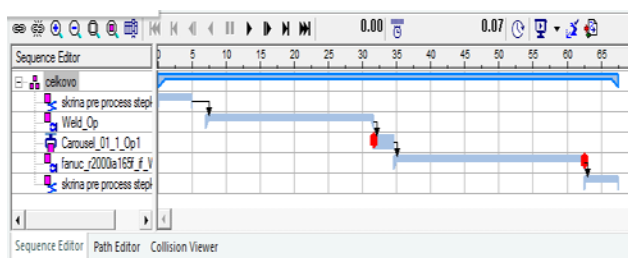


Fig.6 Sequence Editor

4. Results and discussion

The proposed digital model must be tested in terms of the reachability of the industrial robot and the distribution of the individual components of the production system. This prevented the collision between the parts of the production system and the industrial robot with the end effector resp. to remove collisions.

In addition to the interaction of the components of the production system, the load characteristics of each joint were verified. In Fig. 7 Joint value, it is possible to see the measured values in terms of time. Among other things, it is possible to read the actual movement range of individual joints at the proposed trajectory from the overall motion range of individual joints.

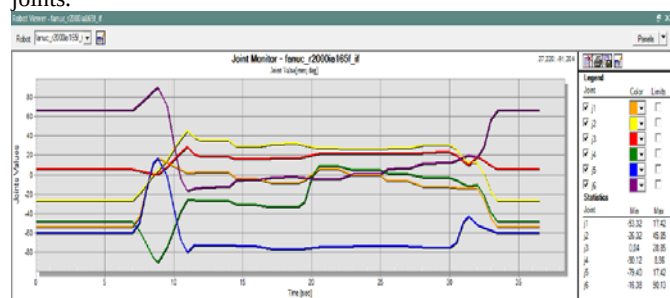


Fig.7 Joint Value

In addition to the load characteristics of the joints, it is possible to read out the greatest speed of movement of individual joints. Thanks to it, it is then possible to retroactively refine the simulation of the process to provide realistic information for implementation into real production.

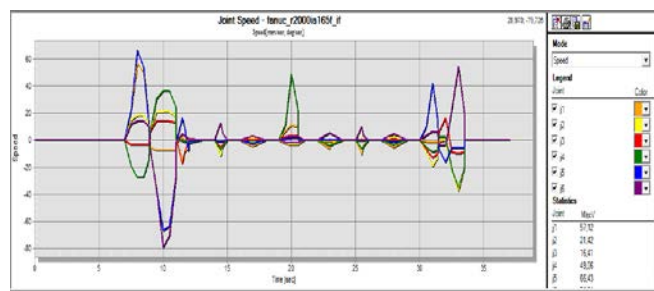


Fig. 8 Joint Speed

This is an option to show the complexity or simplicity of the path when designing larger ranges of joints means consuming more time and energy to perform the operation

5. Conclusion

With an increasing number of industrial robot installations, processes related to automated application design and the use of

CAX systems that target different levels of their development are at the forefront. Software solutions allow you to create simulations across the range of tasks from simple object availability testing within the robot workspace to virtual plant simulation including process, production, logistics, product, and more.

The result of the example used is to verify the reachability of the industrial robot while creating the optimal trajectory of the industrial robot. Using simulation, you can test the kinematic and dynamic properties of mechanisms and systems. Movement of a mechanism or system is controlled by a time sequence. The output is a dynamic simulation that carries information about the movement speeds of individual parts and the trajectory of the industrial robot, the length of the technological operation, the collisions and the layout of the workplace. The total length of the trajectory time interval is the sum of the individual lengths of the time intervals of the industrial robot movements from which the technological operation is composed. The time interval is affected by the speed of movement of the operational and inter-operation processes. The speed of movement of the industrial robot must not affect the accuracy and quality of the technological operation. Consideration must also be given to factors such as inertia, movement, strength or structural strength. An important element is the dispositional distribution of the individual components of the production system, which to a certain extent affects the finding of the optimal trajectory of the industrial robot. The accuracy of the input data and the geometric accuracy of the CAD models influence the credibility of the information obtained.

The creation and more frequent introduction of simulations of various processes in manufacturing, logistics or other industries is an integral part of the Digital Factory concept, which falls under the Industry 4.0 strategy. Simulation facilitates decision making when designing new and optimizing existing production systems. Assuming the correct creation of the kinematic CAD model of the industrial robot and the welding pliers, the obtained simulation data can be considered as data obtained in a real production process, but without significant financial investment.

Acknowledgements

The article was written as part of the Young Researcher project 1383 "Influence of selected attributes in manufacturing systems and sub-systems planning in digital environment" supported by the scientific program - Motivation and support in quality and effectivity elevation of young researchers and scientists. Slovak University of Technology.

6. References

- [1] KLIMENT, M., TREBUŇA, P.: Prínosy softvérového portfólia TECNOMATIX, jeho moduly a súčasti využívané pri modelovaní a simulovaní podnikových procesov a ich optimalizácii. In: *Transfér inovácií*. 2013, p. 25, 158-161.
- [2] Tecnomatix – Process Simulate, Internet source: http://www.plm.automation.siemens.com/en_us/
- [3] Burieta, J. – Kakačka, S. - Fraunhofer IPA Slovakia: Simulácia výrobných a logistických procesov. Internet source: <http://archiv.ipaslovakia.sk/UserFiles/File/ZL/Uspech/2007-%20Uspech%20Simulacia%20vyrobnych%20a%20logistickych%20procesov.pdf>
- [4] NIST, Robotic Systems for Smart Manufacturing Program, 2014, Internet source: <http://www.nist.gov/el/isd/ms/rssm.cfm>
- [5] Trebuňa, P. , Popovič R., Klos S.: Methodology of the Creation of Human and Robot Operation in the Tecnomatix Process Simulate. *Procedia Engineering*. Volume 96, 2014, Pages 483-488
- [6] Siemens PLM Software – TECNOMATIX: Motion Planning Definition File "motionparameters.e". 2015. Pages 4-8.

Digital Image Correlation Analysis of CFRP during compression test

C.Barile, C.Casavola, T.Mizzi, G.Pappalettera, C.Pappalettere

Politecnico di Bari,

Dipartimento di Meccanica, Matematica e Management, viale Japigia 182 -70126 Bari

Abstract

The present paper examines the mechanical behavior of composite laminate subjected to uniaxial compression by DIC (Digital Image Correlation) 3D technique, in particular by analyzing the stability of the buckling equilibrium.

The purpose is how to measure the off-plane displacements, typically founded in buckling, in any point of the ROI (region of interest) of the investigated structure, using a full-field and non-contact measurement technique.

The innovative aspect of this work is therefore to solve this problem through an experimental approach with DIC 3D technique.

1 Introduction

Structures in composite materials are obtained by joining at least two materials, with very different physical and mechanical characteristics. The purpose of this matching is to obtain a final material with better characteristics than those referable to the single initial materials. The composite is generally made up by reinforcement and matrix, giving rise to a solid and continuous material, able to transmit and redistribute internal stress. We can state that composites are non-homogeneous and non-isotropic materials, where the individual constituents are bonded to each other in an insoluble way in order to obtain a final product that combines the best properties of the components. The Fiber Reinforced Polymers (FRP) analyzed in this work are made up by a carbon fiber material (reinforcement) and by epoxy resin as a matrix.

The main carbon fiber properties [1] are: high mechanical strength, high elastic modulus, low density, low crack sensitivity, fatigue resistance and good ability to dampen vibrations. Moreover, the thermal expansion coefficients allow having structures with dimensional stability over a great range of temperature variation.

Epoxy resins [2] represent a group of thermosetting polymeric materials that do not create reaction products when they cure (reticulate) and therefore have a low reticulation retention. They also have good adhesion to other materials, good chemical and environmental resistance, good mechanical properties and good electrical insulation properties. All of these features, together with a remarkable weight reduction combined with high strength (high SWR: strength to weight ratio), make possibility of combining those two materials very appealing in the aeronautic field.

Composites are non-homogeneous and anisotropic materials, so they respond differently to a given load, depending on the direction considered; as a consequence, a proper approach to material

characterization, should employ full-field measurement techniques as, for example, those based on Digital Image Correlation [3].

The three-dimensional DIC technique uses two cameras in order to look at the object from two different directions, obtaining a binocular view that allows to determine the three displacement coordinates (X, Y, Z) for each generic point of the analyzed area [4]. Measurement requires the application of a speckle random pattern on the specimen test.

The 3D DIC technique can also be applied to non-flat surfaces that are displaced off the plane, as in the case of buckling structures; in fact, it provides information about both the shape of the body and the three-dimensional strain field. For this purpose, several images are captured by the two cameras and the speckle pattern for each deformed configuration is analyzed with respect to a reference one.

2 Materials and Methods

2.1 Material description and preparation of the component for measurement

The material analyzed is a composite laminate made up of an epoxy resin mat with carbon fiber reinforcement.

The size of the component subjected to uniaxial compression is 150x100x5 (mm). The layout of the plies, according to the manufacturer's reference is as follows.

Type I layout: FF = 0T / 0F / 0T / 0T / 0F / 0T / 0T / 45F / 0T / SF where F = Fabric, T = Tape

The speckle pattern to be analyzed by DIC was introduced by spraying the specimen (Fig.1). To this scope a matt white spray and a black matt spray were used.

Four electrical strain gauges, two for each side of the pieces, were applied on each specimen [5], in order to evaluate the local strain

resulting from the application of compressive loads. in such a way it is possible to compare local behaviour obtainable by strain gages with overall behaviour obtained by DIC.

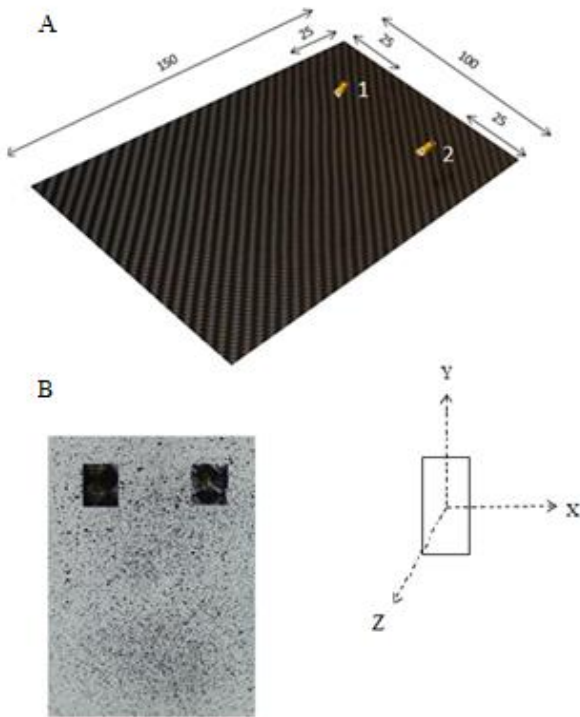


Figure 1. Composite laminate
a) Extensimeter application allowances
b) component prepared with speckle pattern

The strain gauges used are HBM LY1, with a measuring base $l_0 = 3\text{mm}$, gage factor $k = 1.99$.

The strain gauges adopted are able to evaluate deformations in one direction (uniaxial). Strain gages with a resistance of $350\ \Omega$ were used because the composites are bad conductors.

2.2 Description of the compression test machine

Compression test were performed by following the ASTM 7137 (Compression After Impact "CAI") standard defined for the composite. In particular this standard specifies the applied constraints and the ambient condition and the compression rate. Test were performed on a SCHENCK servo-hydraulic machine. In this machine the lower clamp is movable while the upper crosshead is fixed and must be initially positioned with the highest precision in order to avoid torsional or flexural deformations that could introduce errors in the measurement process. The main setting for the test are listed as below:

- Static test, then monotonic test
- Load cell from 250 KN

- Axial channel (being uniaxial compression)
- Control in "displacement rate" ($1.25\ \text{mm} / \text{min}$ until breakage [5])
- Acquisition frequency of 10 HZ

2.3 Configuration of the measurement chain

For a greater accuracy of the tests and to measure the variables involved in the phenomenon of instability of the specimens, a measurement chain was required to complete the reading of displacements and deformations in a suitable manner.

In order to measure displacements and deformations of the whole surface of the specimens in the field three - dimensional, the Dynamics Q400 system with ISTR4 4D software was used.

It includes two Manta industrial cameras, with Ricoh 16mm lenses, fixed on the same support in order to avoid vibrations. System also includes a 4-channel data acquisition and synchronization unit and a light source.

Lighting is used to ensure that the speckle pattern on the specimen, once acquired, has a fairly wide grayscale span range; this means that the background is sufficiently clear (white) and dark (dark) without going into saturation in areas under DIC analysis , but also ensuring uniformity of luminance in these same areas.

It has been chosen to use an optic with a reduced focal length because the latter allow the capture of sufficiently large test specimens to monitor the whole component.

The cameras were coupled to a National Instruments® NIDAQ 9171 acquisition card which allows analog to digital conversion of the acquired signal.

To synchronize acquisition with the start of the test, a trigger signal exiting from the loading machine was sent to the acquisition system by a BNC cable.

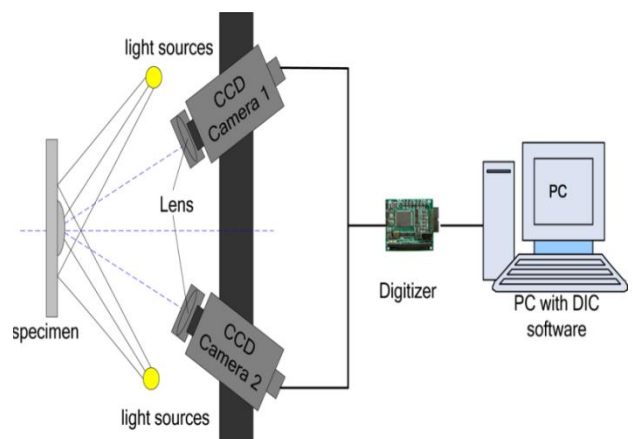


Figure 2. Schematic of a complete 3-D DIC system [6]

Settings for the DIC system are listed below:

- Distance between cameras $l=40\text{cm}$
- Distance between lens and piece $d=50\text{cm}$
- Inclination angle of the cameras $=21.8^\circ$
- Diaphragm opening $=f/8$

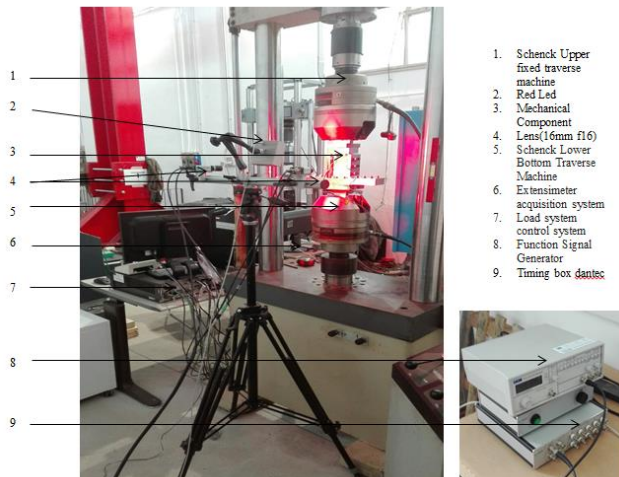


Figure 3. Overview of experimental set-up

The adopted compressive test fixture is shown in Figure4.

It utilizes adjustable retention plates to support the specimen edges and inhibit buckling when the specimen is -loaded.

The fixture consists of one base plate, two base slide plates, two angles, four side plates, one top plate, and two top slide plates. The side supports are knife edges, which provide no restraint to local out-of-plane rotation.

The top and bottom supports provide no clamp-up, but provide some rotational restraint due to the fixture geometry (the slide plates have a squared geometry and overlap the specimen by 8 mm [0.30 in.]). The fixture is adjustable to accommodate small variations in specimen length, width and thickness. The top plate and slide plates, which are not directly attached to the lower portion of the fixture, slip over the top edge of the test specimen. The side plates are sufficiently short to ensure that a gap between the side rails and the top plate is maintained during the test.

The configuration of the panel edge-constraint structure can have a significant effect on test results. In the standard test fixture, the top and bottom supports provide no clamp-up, but provide some restraint to local out-of-plane rotation due to the fixture geometry. The side supports are knife edges, which provide no rotational restraint.

Edge supports must be co-planar. Results are affected by the geometry of the various slide plates local to the specimen.

Results are also affected by the presence of gaps between the slide plates and the specimen, which can reduce the effective edge support and can result in concentrated load introduction conditions at the top and bottom specimen surfaces.

Additionally, results may be affected by variations in torque applied to the slide plate fasteners; loose fasteners may also reduce the effective edge support.



Figure 4. Edge-constraint structure adopted in the experiment

3 Results and Discussion

In order to measure the displacements and deformations of the entire surface of the composite in the three-dimensional field, the mechanical uniaxial compression test was monitored using the 3D system, acquiring a series of images that represent the displacement off the plane(z-displacement), starting from the first non-deformed configuration of the component until it came to break, with acquisition frequency of 1Hz, for the entire duration of the test.

The analysis of these frames (Fig.5), at certain steps, allows to view the buckling in CFRP subjected to uniaxial compression.

The images are captured and correlated by setting a “high accuracy” mode that allows a correlation with a 3d residuum of less than 0.4 pix, a facet size of 19 pixels and an accuracy of 0.1 pixels that allows locating 1180 grid point in the region of interest (ROI) of composite laminate.

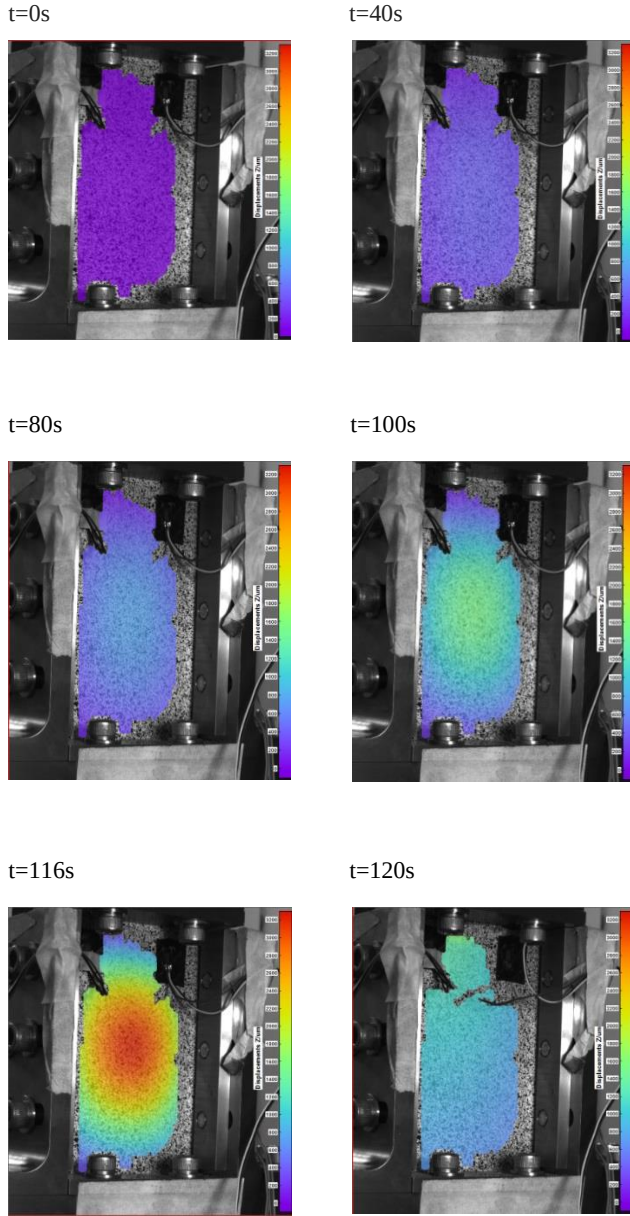


Figure 5. Frames of out of plane displacement of the composite taken by DIC at various steps

From the analysis of the images, the following considerations can be done: the component, due to the adopted fixtured and the low displacement rate implemented (1.25 mm / min) is subjected, in the first load steps to low out of plane displacement values (e.g. 400 μm at the center of the specimen at step $t = 40\text{s}$).

The component begins to buckle after 80 seconds from the beginning of the test when an out of plane displacement equal to 800 μm is recorded. After 116 s out of plane displacement becomes more evident and it reaches a value of 3200 μm while the specimen broke soon after, namely at 120 seconds.

Temporal load law is reported in Fig.6.

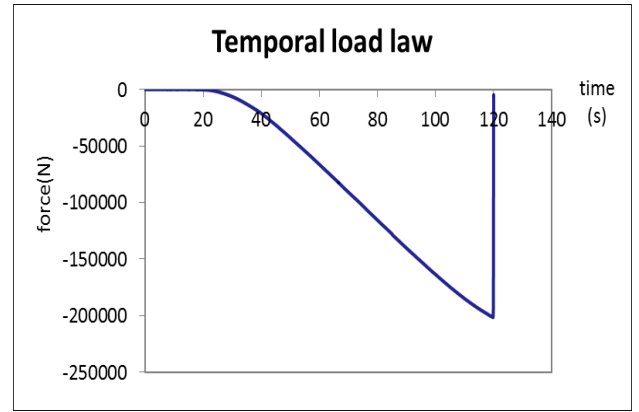
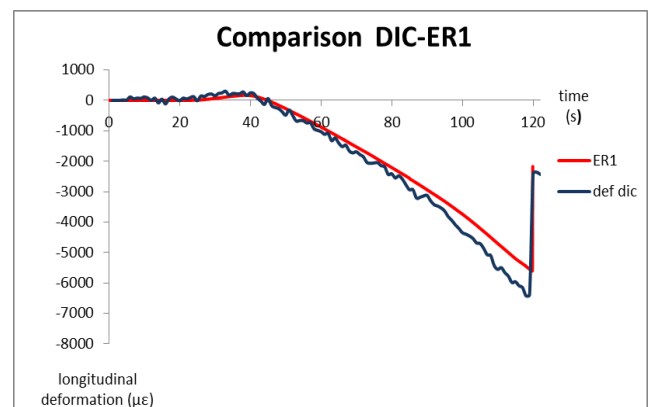


Figure 6. Temporal load law of the machine

There is a first hyperbolic trend in the first 40 s until reaching a load of about -21kN. At this point the first instability of the component is recorded because some out of plane displacement are observable at this point. Successively there is a linear behavior, which terminated at $t = 80$ seconds. From that point until 116 seconds a slight slope change occurs as a result of the buckling of the specimen as it is inferable by observing DIC images.

The abrupt cut of curve is caused by the breaking of the specimen with the consequent detachment of the supporting LVDTs immediately after reaching maximum load, recorded at the break of the sample at $t = 120$ s corresponding to $F = -200$ kN.

Using two additional electrical strain gauges at known locations [5] it has been possible a comparison between the ϵ_{yy} - t results obtained by ER and DIC; to verify the accuracy the deformation ϵ_{yy} value was read across the strain gauges 1 and 2 and it was compared to the corresponding DIC reading along a gauge of 3 mm corresponding to the measurement base l_0 of the strain gauges, located at the points where ER were applied (Fig.7)



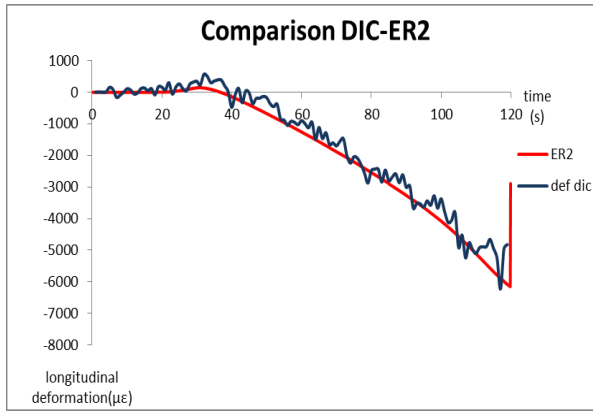


Figure 7. Comparison of longitudinal deformation reading between DIC and strain gauge

From the comparison between the two techniques it is possible to infer that there is some overlap in the deformation trends. For one of the two considered ER lower deformation where recorded; this may be due to a misalignment error in the mounting of the two strain gauges, in fact there is a certain shift between the left and right of the specimen with respect to the center of the latter in favor of the left area.

It should also be observed that higher level of noise affects the data obtained by DIC as reported in Fig.7 and this is due to the high luminance reflected by the bounding structure, on the right side where the ER2 is mounted.

In this case a "smoothing" operation is preferable.

In Fig.8 the trend of longitudinal deformation along the cross section of the specimen is shown, at the step $t = 116s$.

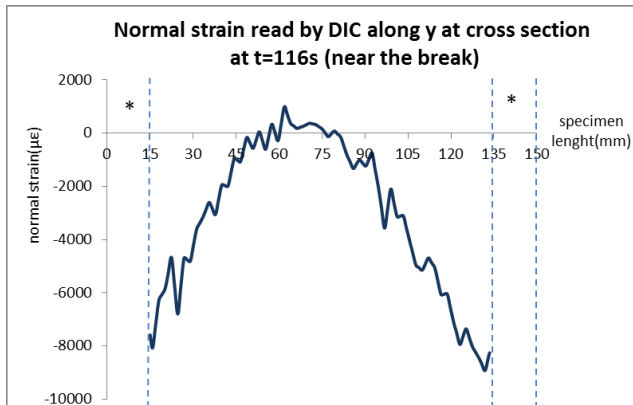


Figure 8. Normal strain ϵ_{yy} at $t=116s$

It can be noticed that the component has a normal strain ϵ_{yy} negative in the outer areas, according to a nearly symmetrical pattern with respect to the center of the specimen. At the center the deformations are positive then the specimen stretches slightly.

There is a certain shift towards the top, in fact it is precisely in that area, exactly 15 mm from the 0 that breaks. In Fig 9 the shear strain recorded after 116 s is reported

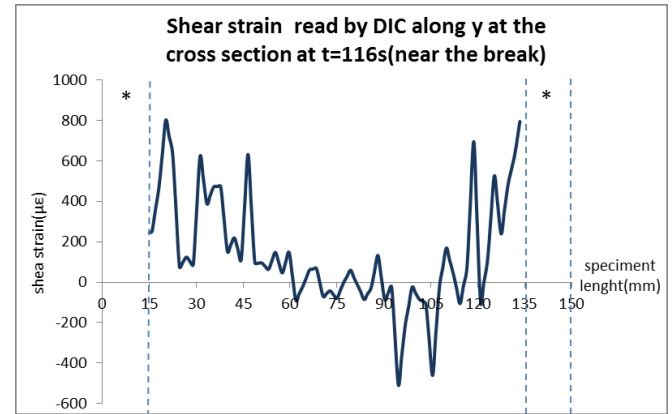


Figure 9. Shear strain γ_{xy} at $t=116s$

Interesting considerations can be made on the previous graph.

It was noted that the maximum shear strain value can be traced from 15 to 20 mm from the zero and that is the point where the sample starts to break.

This may be understood in the framework of the continuum mechanics theory. Such deformation, in fact, is due to the sum of the mixed derivatives of the x e y displacements in response to the angular deformation of the composite in that area that determines delamination effects.

Previously indicated asymmetry was also found by analyzing the out of plane z displacements (Figure 10), in fact despite of the trend being typical of a gaussian, the lower part has a different slope than the upper one.

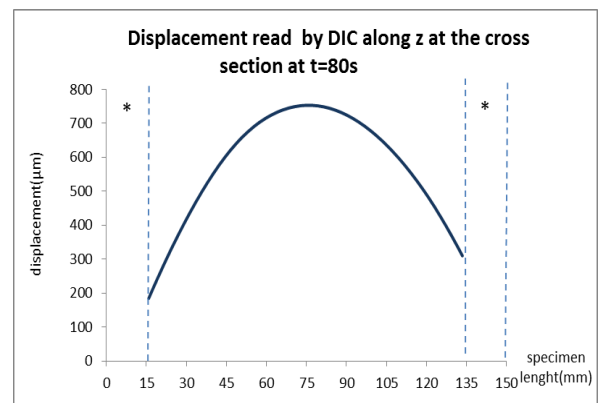


Figure 10. Out of plane displacement w at $t=80s$

The off-plane displacement behaviour indicates how the specimen goes in buckling exactly at the center with a value of $w = 750 \mu m$ at $\frac{l}{2} = 75mm$.

It can be stated, however, that although the specimen was constrained to a structure designed to avoid buckling, the

phenomenon of elastic instability is, however, at a critical load which is certainly higher than that referenced by the bibliography for a simply anisotropic supported plate subject to uniaxial compression [7].

The areas indicated by * do not display information since in those areas the DIC was unable to recognize the speckle pattern and therefore could not read the u,v,w displacements along x, y, z.. The underlying reason for this lack of information is that the particular constrained structure creates shadow zone that do not allow the lenses to recognize the white and black points typical of the speckle pattern.

4 Conclusions

In this paper the mechanical behavior of composite subjected to compression loading was reported as analyzed by Digital Image Correlation.

Electrical strain gauges at known locations [5] were also used in order to compare local results obtained by ER and full-field results obtained by DIC. This comparison underlines the possibility to apply the 3D DIC technique as an integration or a replacement of traditional measuring instruments to calculate displacements and deformations on the whole surface of the specimen. Allowing also reduction of some experimental bias as those connected with ER misalignment. Moreover, DIC is able to capture asymmetries in the behaviour of the sample, and this is a fundamental aspect for materials that are non-homogeneous and anisotropic.

Acknowledgment

Research co-funded by *Fondo di Sviluppo e Coesione 2007-2013* – *APQ Ricerca Regione Puglia* “Regional program to support smart specialization and social and environmental sustainability – FutureinResearch”

References

- [1] F.C. Campbell Jr - *Manufacturing Technology for Aerospace Structural Materials*
- [2] I.K.Varma, V.B.Gupta, - *Thermosetting Resin Properties*, Volume 2; (ISBN: 0-080437206); IIT, Delhi, India.
- [3] Sutton, M.A., J.J. Orteu, and H.W. Schreier - *Image Correlation for Shape, Motion and Deformation Measurements*. Springer Science, 2009.
- [4] Ajovalasit, A. - *Analisi sperimentale delle tensioni con la fotomeccanica*, 2009
- [5] ASTM standard 7137 (Compression After Impact "CAI")
- [6] Yong-Kai Zhu ¹, Gui-Yun Tian ^{1,2,*}, Rong-Sheng Lu ³ and Hong Zhang ² - *A Review of Optical NDT Technologies*
- [7]. N. S. Trahair - *Flexural torsional buckling of structures*, CRC Press, 1993

SIMULATION AND MOTION CONTROL OF INDUSTRIAL ROBOT

Yaser ALAIWI¹, Aşkın MUTLU¹

Faculty of Engineering – Department of Mechanical Engineering, Istanbul University, Turkey¹
yaser.alaiwi@istanbul.edu.tr, askin@istanbul.edu.tr

Abstract: This research proposes a simulation of a Stäubli TX90 robot based on Simulink Toolbox of Matlab. The goal is to predict the position and trajectory of its end-effector, with high reliability. The simulator takes into consideration loading, deformations, calibrated kinematic parameters, and all eventual sources of disturbance. A comparison between real and simulated data reveals the reliability and the accuracy of the simulator.

KEYWORDS: SIMULATION, PID CONTROL, STÄUBLI TX90, INDUSTRIAL ROBOT

1. Introduction

This robot has six degrees of freedom; all of them are rotational, driven by servo motors. The robot has the appearance that can be seen in Figure 1:

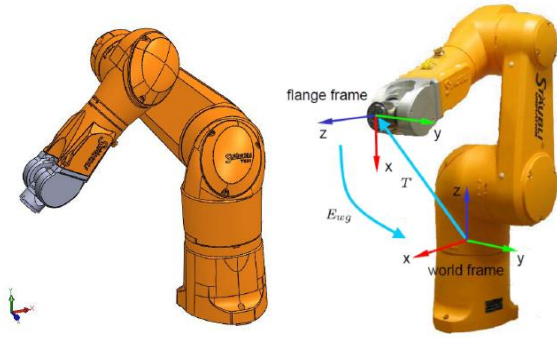


Figure 1: Stäubli Robot TX90 Real view and SolidWorks Design

The simulation should provide an accurate position of the robot's end-effector. The TX90 robot is a serial manipulator robot with six rotational joints. The link frames and the kinematic parameters of the TX90 robot, following the notations of the modified Denavit and Hartenberg method proposed by Khalil and Kleinfinger [1], are shown in Figure 2.

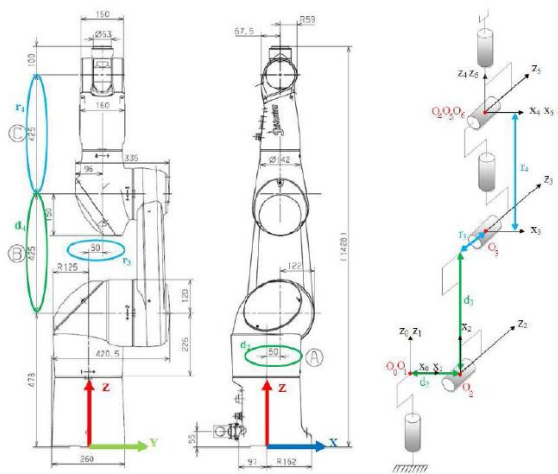


Figure 2: Kinematic description of the Stäubli TX90 robot

The kinematic parameters (α_j , d_j , θ_j , r_j , β_j [5]) were calibrated previously by using an autonomous calibration method [2, 3, 4] which aims to identify the difference between the nominal and the real values of the kinematic parameters and then to have a better knowledge of the position of the end-effector (rate of knowledge improvement is about 94 %). The nominal values of the kinematic parameters (in bold) D-H are shown in Table 1.

Table 1. The Standard Kinematic model in Denavit-Hartenberg Convention

j	α_j	a	θ_j	d_j
units	[rad]	[mm]	[rad]	[mm]
1	-1.5708	50	0	350
2	0	425	0	50
3	-1.5708	0	0	0
4	1.5708	0	0	425
5	-1.5708	0	0	0
6	0	0	0	100

Previously, identification of the dynamic parameters, and identification of the elastic parameters and the joint stiffness matrix were carried out on the TX90 robot [4]. These parameters are taken into consideration in the simulator for the nearest representation of the reality.

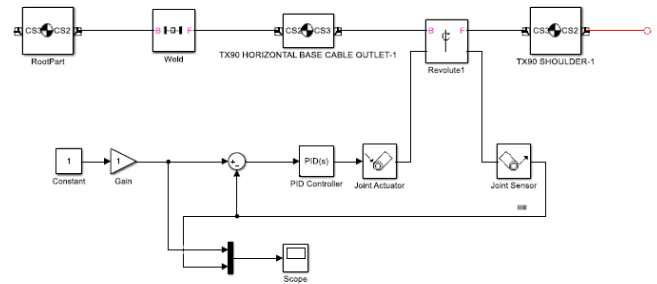


Figure 3: PID Controller diagram in Simulink

2. Description of the Simulation Tool

To model the dynamics and the control of the robot, the simulation tool must be coupled with Simulink blocks and use Matlab functions in order to compute for example: The inverse kinematic model, the trajectory generation and the control blocks.

The chosen tool to simulate the TX90 is SimMechanics [6,7,8] which is a sub-tool of Simulink®. Consequently, its models can be interfaced with ordinary Simulink block diagrams which speed up the simulation and integrate everything in the same environment. Moreover, it is simple to use and its block set consists of seven sub-libraries that represent the following: bodies, joints, sensors (joint sensors, body sensors), actuators (joint actuators, body actuators), gearboxes, constraints and drivers, and force elements.

SimMechanics tool allows to:

Model all the elements of a multi-body system (i.e. bodies, joints, connections, forces) in Simulink;

Import full models from CAD systems (i.e. Stäubli SolidWorks CAD [9]), with the properties of inertia, lengths, angles;

Generate a 3D animation to visualize system dynamics.

3. Trajectory Generation, Control and Simulation in SolidWorks

The approach used for the generation of trajectories in the case of the TX90 was not provided by the manufacturer for reasons of confidentiality. The study of the position and the velocity signals (given by the "Stäubli recorder") and the calculation of the accelerations (derivation of the velocity) show that the approach is applied in the joint space using the trapezoidal velocity law. This approach provides during movement: a continuous velocity (ensures a minimum time by saturating the velocity and acceleration at the same time) and a continuous acceleration (replaces the acceleration and braking phases by a law of the second degree and therefore the position is a law of the fourth degree) [10].

On the other hand, only the name of the controller used by Stäubli has been provided by the manufacturer through a confidential agreement and so it is not possible to present it in this paper. The controller and the trajectory generations blocks are designed under the environment of Simulink.

We can see the control sequence of Stäubli Robot Tx-90 in Figure 4 and the Simulink Diagram with PID controllers in the following Figure 5.

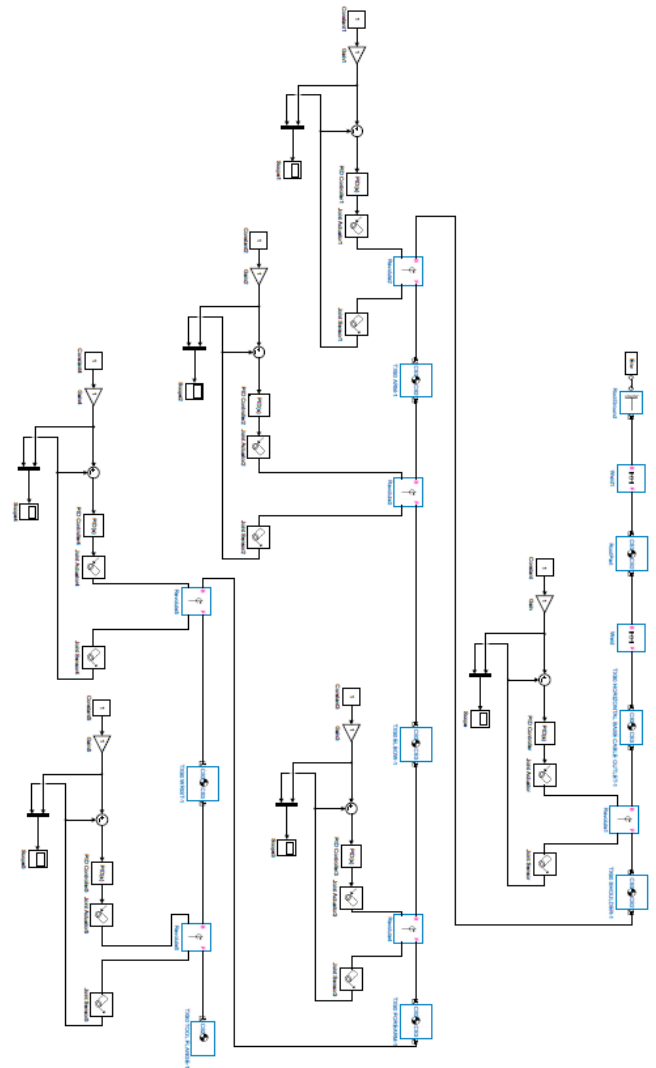


Figure 5: Simulink Diagram with PID controllers



Figure 4: Control Diagram of Stäubli Robot Tx-90

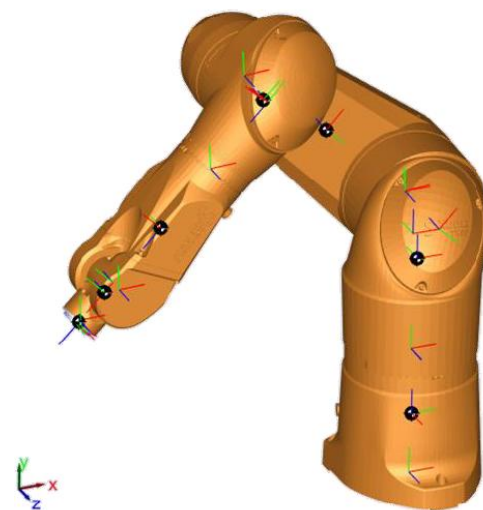


Figure 6: Three-dimensional animation of the TX90 robot in Simulink

We built three dimensional model from technical drawings for Stäubli Robot TX90 and after making the proper assembly mates we could make motion analysis. we can see the simulation results for tracking this arbitrary trajectory (3600 mm length) in a time of 6 seconds that means total velocity is 0.6 m/s Figure 7.

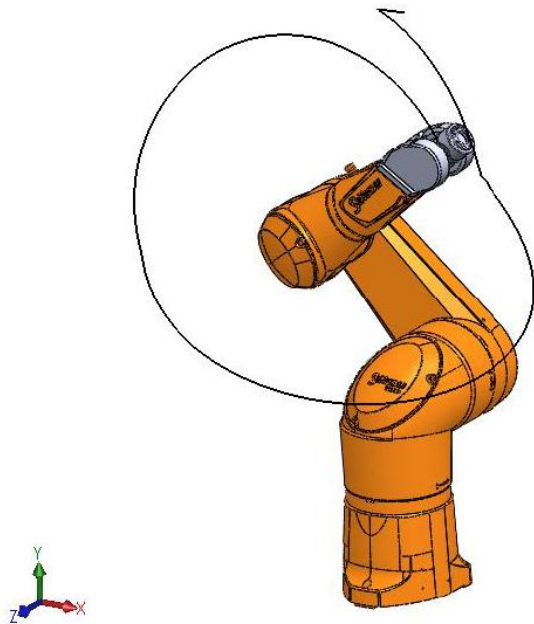


Figure 7: SolidWorks Trajectory tracking and Motion Simulation

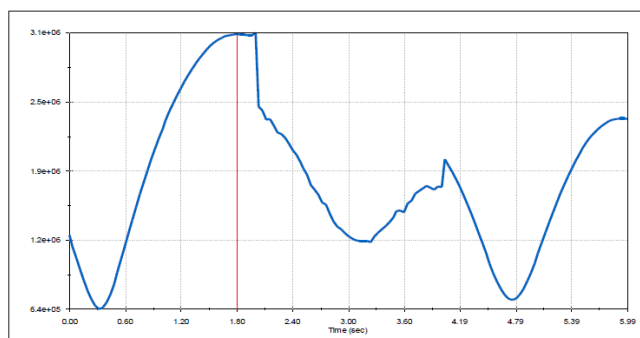


Figure 8: Angular Momentum

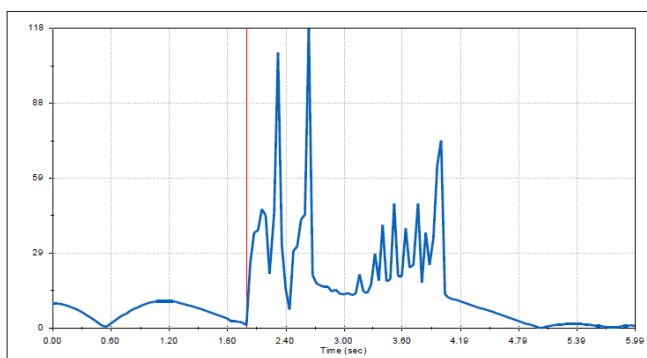


Figure 9: Motor Torque

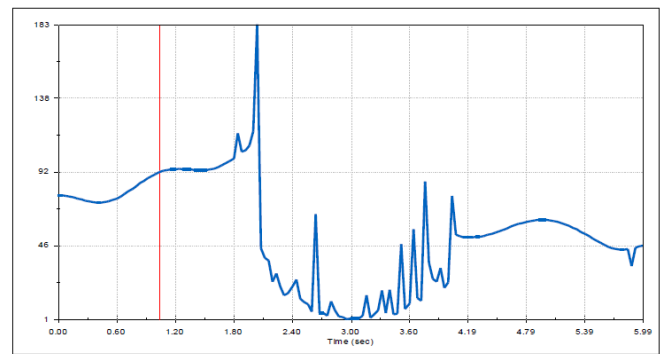


Figure 10: Angular Acceleration

4. Conclusion

This research has presented the implementation of the Stäubli TX90 simulator using Sol idWorks and SimMechanics which is an interactive three-dimensional modeling of mechanical systems in Simulink®. It allows building simulations and automatically generates 3D animations of multi-body systems such as robots. Blocks representing all external perturbations (deformations, cutting forces, flexibilities, loads) have been integrated into this simulator. This simulator is able to predict the position and trajectory of the end-effector according to the loading and deformation in order to represent reality with high reliability.

The simulation results indicate that SimMechanics can be used for modeling other robots with the same morphology as the TX90, (i.e. anthropomorphic, open, series). Block parameters defining for example the different bodies, joints, kinematic models (i.e. MGI, MGD) can be easily modified to be adapted to other robots. Moreover, the simulator can be used to validate the feasibility and to predict errors of other maintenance operations that need high precision such as welding.

5. References

- [1] W. Khalil and J.F. Kleinfinger, A new geometric notation for open and closed loop robots, in International Conference on Robotics and Automation, San Francisco, CA, April, 1986, pp. 1174–1180.
- [2] H. Hage, P. Bidaud, N. Jardin, Practical consideration on the identification of the kinematic parameters of the Stäubli TX90 robot. The 13th World Congress in Mechanism and Machine Science, Guanajuato, Mexico, 19-25 June, 2011.
- [3] S. Besnard, Etalonnage géométrique des robots séries et parallèles, Doctoral dissertation, Nantes, France, September, 2000.
- [4] H. Hage, Identification et simulation physique d'un robot Stäubli TX90 pour le fraisage à grande vitesse, doctoral dissertation, Paris, France, February, 2012.

- [5] S. A. Hayati, Robot arm geometric link calibration, in proceedings IEEE International Conference on Decision and Control, San Antonio, December, 1988, pp. 1477_1483.
- [6] Information on <http://www.mathworks.com/products/simmechanics/>
- [7] Y. Shaoqiang, L. Zhong, L. Xingshan, Modeling and simulation of robot based on Matlab/SimMechanics, in Proceeding of Control Conference 27th Chinese, 2008.
- [8] L. Brezina, O. Andrs, T. Brezina, NI LabView—Matlab SimMechanics Stewart platform design, Applied and Computational Mechanics 2 (2008) 235–242.
- [9] Information on <http://www.staubli.com>
- [10] W. Khalil, E. Dombre, Modélisation, identification et commande des robots, second edition, Paris, 1999.

INFORMATION - CALCULATION METHOD FOR ENERGY EFFICIENCY RADIANT HEATING SYSTEMS IN INDUSTRIAL PREMISES

Hristozov Daniel Eng.¹, Madzharova St. Asst. Prof PhD., Eng.¹, Bozukov N. Prof. PhD, Eng¹, Petrova T. Assoc. Prof. PhD², Bakalov I. Asst. Prof. PhD²,

Dept. of Informatics and Statistics, Faculty of Economics, University of Food Technologies, Plovdiv, Bulgaria¹

Food Research and Development Institute - Plovdiv, Plovdiv, Bulgaria²

d_hristozov@uft-plovdiv.bg, nitani@abv.bg¹, bozukovnanko@abv.bg¹, dorrapirova@abv.bg², ivvanbakalov@abv.bg²,

Abstract: The paper considers a model and an algorithm for predicting the thermal regime in work (home) accommodation with radiant heating. The algorithm allows the analysis and design of cost-efficient option for realization of this type of heating.

Keywords: INFORMATION-CALCULATION METHOD, ENERGY EFFICIENCY, RADIANT HEATING SYSTEM

1. Introduction

Temperature, relative humidity, air mobility in the occupied areas, the surface temperature of the surrounding building elements, and the temperature of the equipment in the facility prove essential to the flow of vital processes in the human body.

The multifactor system determining the thermal conditions is the basis for choosing a heating system of the manufacturing facilities. Serious attention should be paid to all these factors, since not only the quality and functioning of the equipment situated in the production room depends on this, but also has an impact on the effectiveness of workers who spend most of their time indoors.

Constant temperature of the air in the manufacturing facilities is usually needed, without radical changes which could have a negative impact on the installed equipment and the employees. It is also necessary to take into account regulatory requirements in terms of explosion and fire safety. The production facilities themselves usually occupy a considerable area, on which the different production or technical equipment is installed. Ceiling height is not small, which creates additional difficulties when choosing a suitable heating system.

2. Solutions for radiant heating

The use of radiant heating allows the obtaining of better results in the heating of production premises with respect to the uniformity of the temperature distribution of air in the vertical and horizontal [1]. The increased surface temperature of the surrounding elements allows the maintenance of a lower air temperature while preserving the thermal comfort of the workers. With these, the heating is via infrared heat energy radiated from emitters situated directly above the work area. By reflectors, this energy is directed to the heated area, while both the air and the surrounding surfaces are heated. Part of the indicated advantages of radiant heating also includes the short period necessary to achieve thermal comfort. In radiant heating with radiating bands is advisable to bear in mind that they are not recommended for premises, which are expected to accommodate high equipment and bulk materials. They are considered very inappropriate for low premises.

Infrared emitters can work with gas or electricity. Depending on the surface temperature there are light and dark emitters.

High temperature tubular heaters are also considered very appropriate for production halls. The heating fixture consists of a bundle of tubes coated with heat-insulated tin jacket. The number of tubes in a bundle can vary, and it is typically from 2 to 6, and their diameter usually ranges from 180 to 600 mm. Their length is determined depending on the shape and dimensions of the room.

The heating is by direct combustion of gas or diesel. The emitted flue gases are disposed outside the premise. In practice, systems with recirculation or direct current systems are used in

heating of premises with high temperature piping.

Sizing of heating systems

Heating systems are sized for indoor air according to design regulations. These parameters are determined on the basis of a set of hygienic and economic considerations. Thermal comfort is defined by temperature conditions satisfying the occupants of the room. It cannot be unequivocally that is why, permissible temperature conditions are admitted, which underline in the basic methodologies for calculating HVAC (heating, ventilation and air conditioning) systems [2].

An important point in the sizing of the heating system is the determination of heat losses. It is customary to calculate them in stationary conditions of constant temperatures, the characteristic of structural elements, etc. In their determination it is necessary to take into account the fact whether the heating will be with or without interruption.

It should be kept in mind that the operation of heating systems is associated with high costs, formed mainly from energy consumption.

It is recommended even at the design phase to take measures to reduce them. Among the possible measures are to allow for good thermal insulation of buildings; regeneration and recuperation of the heat of the exhaust air; choice of secure system for automatic regulation and others.

3. Research method and results

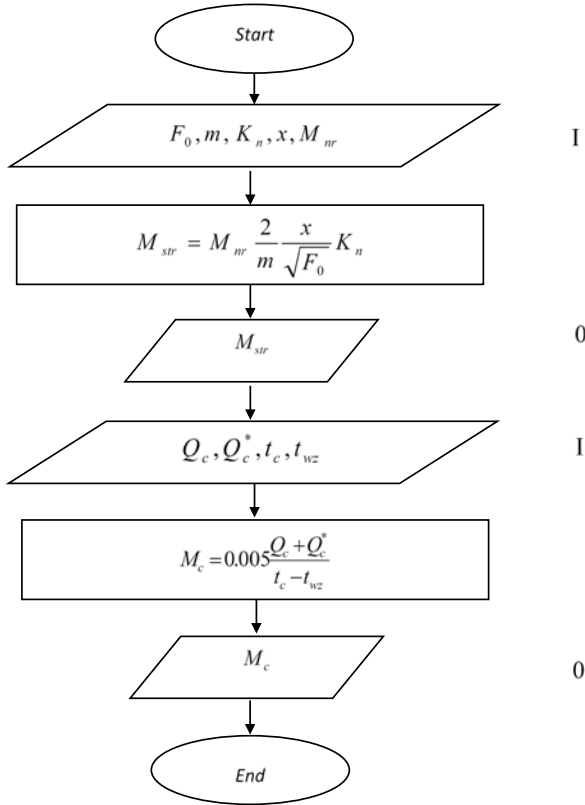
The idea is to develop an approximate mathematical model of the complex heat and mass transfer processes occurring in a room with radiant heating and ventilation. The mathematical model constitutes a system of equations for the air and heat balance in the specific volume and the surrounding surfaces of the room. The site is a production room, in which a radiant heating system is installed, without other heat sources. The heat flows from the radiating sources are: convective currents which are located in the top part of the room and give warmth to the interior walls and radiant component. The interior surfaces transfer heat by convection and radiation in the closed premises. Part of the heat is lost by transmission through the outer wall of the building.

The air is fed in the direction of the work service area in quantity M_{nr} and is given to the upper area with an expenditure $M_b = M_{nr}$. At the level of the upper work service area the expenditure of air in the stream is M_{str} . The increase of air flow is due to air circulation, which constitutes a drop in the flow. The cross-border flows are shown by dashed lines in figure 1. The calculated volumes are chosen: region (an area with a constant

presence of people); the volume of the supplied air flow and the wall convective flows. The direction of the wall convective flows depends on the ratio of the temperature of the inner and outer surfaces and the ambient air.

The air temperature in the service area t_{wz} is formed by mixing the air from the air flow for heating, the wall convective flows and the convective heat from the inner surfaces of the floors and the walls. In reporting the developed scheme for heat exchange and circulation of air flow (figure 2, 3) the algorithm is drawn for calculating the heat and air balance for the given volume.

The air flow in the range [4], defined by the convective flow is:



m - damping ratio

F_0 - section of the inlet air-distributing diffusers, [m²]

x - the distance from the diffuser to the point of basic service area, [m]

t_c - temperature of the inner surface of the external wall, [°C]

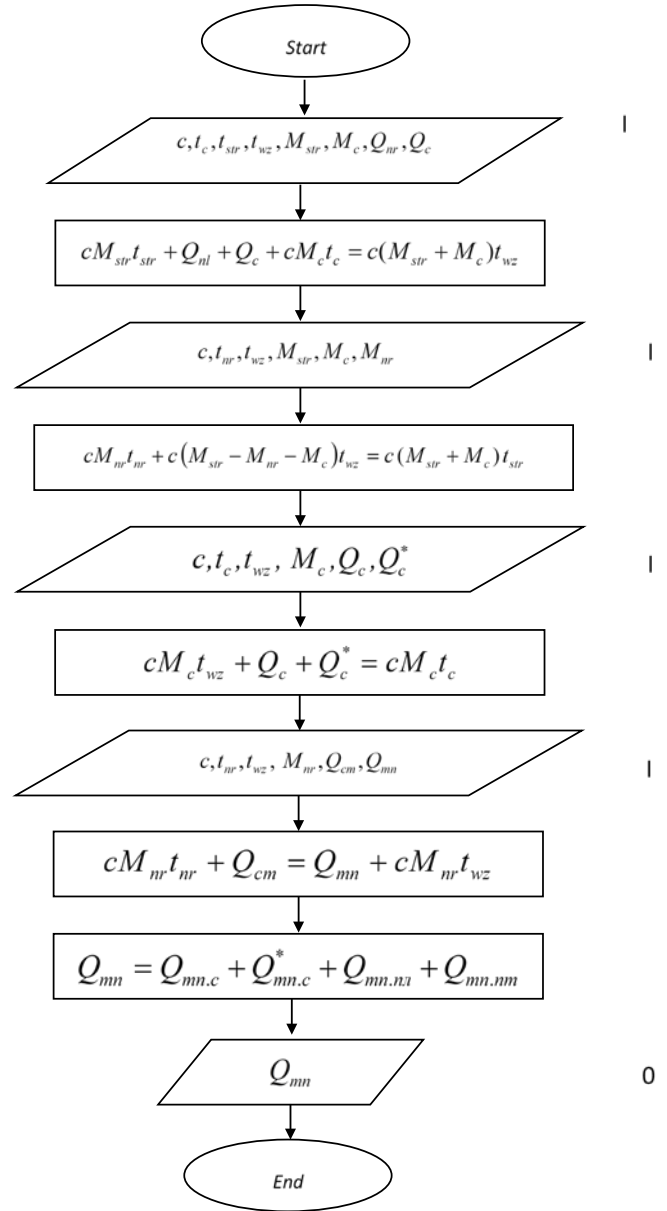
C - specific heat capacity, [J/(kg.°C)]

Q - power of the gas radiant system, [W]

Q_c и Q_c^* - convective heat transfer from the inner surfaces of the walls in the service area, and of the wall above the service area, [W]

t_{str} , t_c , t_{wz} - air temperature in the inflow into the work area in the wall convective flows and work area, [°C]

Q_{mn} - heat loss in the room, [W] (equal to the amount of heat loss through the building envelope).



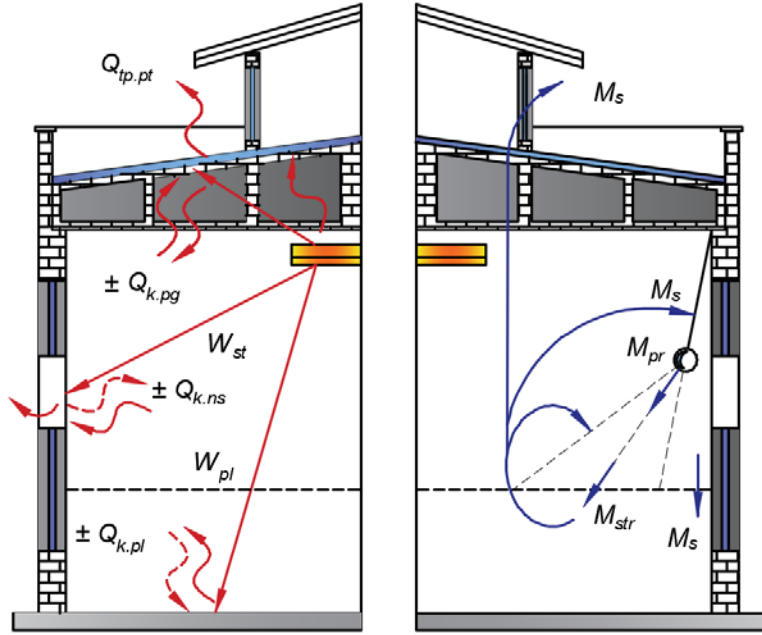


Figure 1

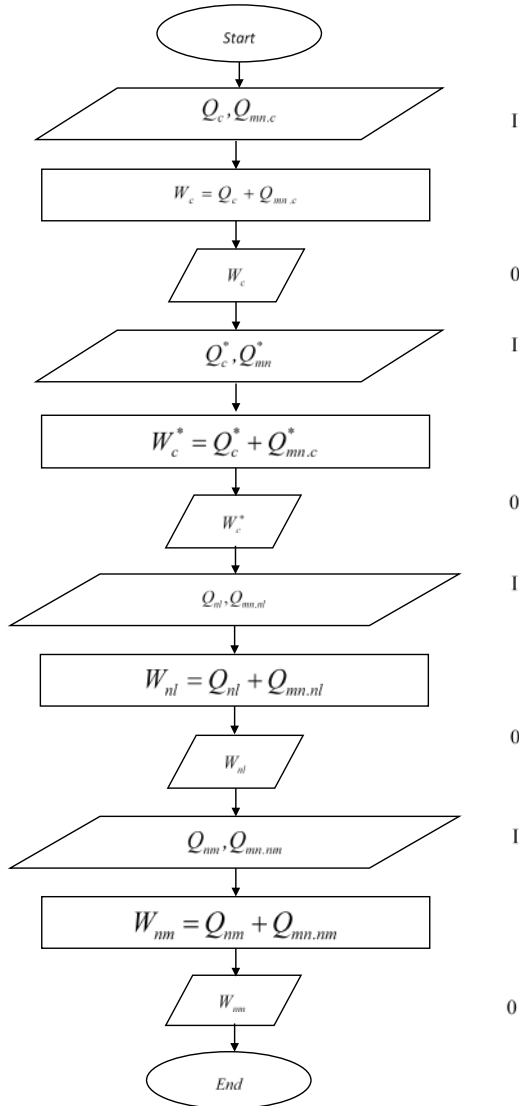


Figure 4

Q_c, Q_c^*, Q_{nl} и Q_{nm} - convective heat transfer from the inner surfaces into the service area - walls over the service area, the floor and the surrounding walls, respectively, $Q_{mn,c}, Q_{mn,c}^*, Q_{mn,nl}, Q_{mn,nm}$, - heat losses from the relevant structures, W_c, W_c^*, W_{nl} и W_{nm} - radiant heat flows from the source flowing into these surfaces.

Convective heat loss is determined by:

$$Q_j = m_j F_j \Delta t_j^{4/3}, \quad (1)$$

m_j - factor determining the direction of heat flow with reference to surfaces, F_j - surface area, [m²], Δt_j - temperature differential between the environment and the surfaces, [°C], j - index indicates the type of surfaces.

Heat loss can be expressed through:

$$Q_{mj} = F_j \frac{\tau_j - t_H}{R + R_H}, \quad (2)$$

t_H - outside air temperature, [°C], t_j - the temperature of the inner surfaces of the outer walls, [°C], R и R_H - resistances of heat transfer, [m²K/W].

The radiant heat flow from the source of radiation W_j at an arbitrary orientation of the radiating system and the surrounding surfaces is calculated by:

$$W_j = c_0 \varepsilon_{ij} H_{ij} \left[\left(\frac{T_i}{100} \right)^4 - \left(\frac{T_j}{100} \right)^4 \right], \quad (3)$$

C_0 - emission ratio of blackbody, $[W/(m^2 K^4)]$, ε_{ij} - degree of blackness, H_{ij} - area of the radiating surfaces, $[m^2]$.

The solutions of the resulting mathematical models of the processes of heat and mass transfer [3] under the joint action of radiant heating and ventilation allow the obtaining of basic characteristics of the thermal regime in the design of systems for radiant heating of various buildings equipped with ventilation systems.

4. Conclusion

Heating systems with infrared emitters are the preferred solution for heating of premises in which organic dust or fire hazardous aerosols are not emitted.

They are recommended for buildings with low thermal insulation and for heating of separate areas in unheated premises. Among their advantages are small heat inertia, the ability to operate in the mode of a general or zone heating, economical operation, the ability to heat open areas, high reliability and easy maintenance.

Their disadvantages are mostly related to the high temperature of the radiating plate, the need of ventilation for removal of waste products from the combustion in using gas emitters. It should be kept in mind that it is not recommended to install infrared emitters in premises with increased fire hazard and in areas where there are materials which under the influence of infrared radiation modify their properties.

References

1. Банхиди А. (1985) Лучистое отопление. А. Банхиди, Л. Мачкаши -М.: Стройиздат, pp. 464
2. Григорьев В.А. (1988) Теоретические основы теплотехники/ В. А. Григорьев, В. М. Зорин// Справочник.- М.: Энергоатомиздат, pp. 560
3. Джалурия Й. (1983) Естественная конвекция/ Й. Джалурия// Тепло- и массообмен. -М: Мир, pp. 399
4. Наумейко А.В., П.В. Кузнецов, Ю.И. Толстова, Р.Н. Шумилов (2003). Энергоэффективные системы отопления: Учебное пособие. Екатеринбург

FULL USE OF MATHEMATICS – FOUNDRY

Bushev S., Associate Professor, PhD, Eng.

Institute of metal science, equipment and technology with hydro- and aerodynamics center "Acad. A. Balevski"
Bulgarian academy of sciences, Sofia 1574, 67 "Shipchenski prohod" Str. Bulgaria Republic
stbushev@abv.bg

Abstract: In this work, we present the necessity of using the full mathematics in the industrial branch of machine building of the example of the foundry. Obtaining the necessary structures is accompanied by research work even in micro-foundries, which is provided by powerful and new software products, i.e. knowledge transfer with computational mathematics, physics and education.

Keywords: MACHINE BUILDING, FOUNDRY, CASTING STRUCTURES, MATHEMATICS, EDUCATION

1. Introduction

The importance of mathematics is represented by a general block diagram of "The History of the Development of Knowledge of Civilization from Antiquity to Today" of Fig. 1

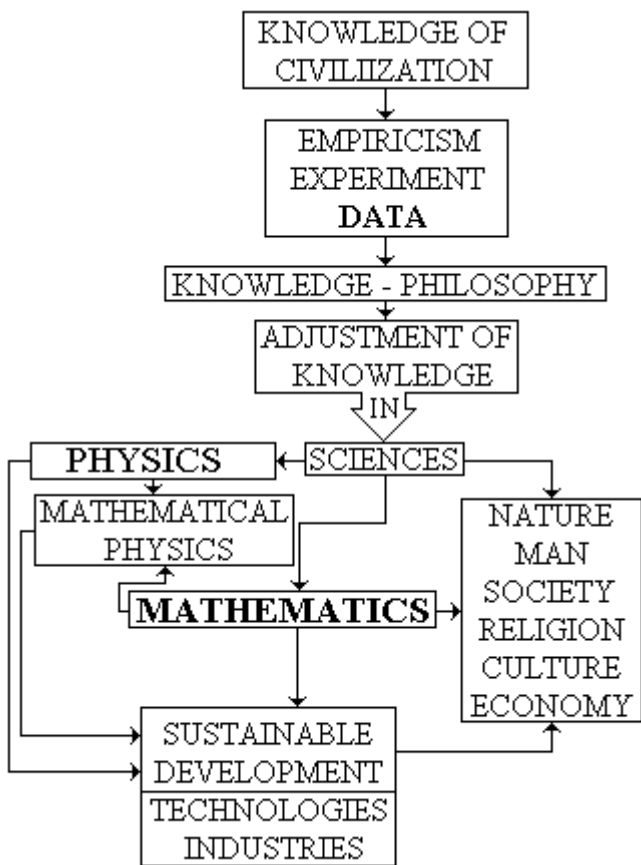


Fig. 1 Block diagram - Developing the knowledge of civilization from antiquity to today [1, 3, 4].

1 follows: 1. Initial knowledge is obtained through empiricism - obtaining and classifying experimental data; 2. Collecting knowledge in philosophy; 3. Knowledge is divided into separate sciences after Christ: 3.1 Physics - 18th Century; 3.2 Mathematics - the 19th and the beginnings of the 20th century; 3.3 Mathematics - Self Development; 3.4 Mathematics - a powerful tool for research: Description of physical processes and phenomena. Any theory is obtained only by using mathematics; 3.5 The term mathematical physics includes natural and theoretical physics; 4. Mathematics is in every area of human activity; 5. Sustainable development of civilization is based on: a sustainable society and economy - a challenge for every government; 6. Civilization only evolves by overcoming crises in society and the economy; 7. The challenge is the restructuring of the world by the fourth industrial revolution [1], involving education throughout every person's life, environmental technologies and industries.

The natural systems and the four main types of interaction forces in nature are classified in Fig. 2

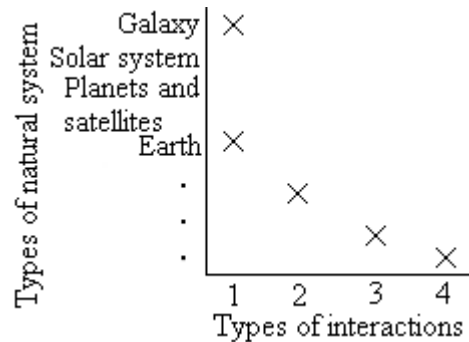


Fig. 2 Scheme - Natural systems and types of interactions [2]: 1 - gravitational interaction (large-scale events in the Universe), 2 - electromagnetic interaction (holds electrons in atoms and binds atoms to molecules and crystals (chemistry, biology)), 3 - strong interaction connects the nucleons (it unites protons and neutrons in the nucleus of all elements), 4 - weak interaction determines the forces acting between the light particles (leptons: electrons, neutrinos and muons) and between leptons and heavier particles).

The purpose of this work is to present the necessity of the complete mathematics in the foundry.

2. Foundry - physical and technological processes of structure formation

The casting structures are obtained in phase transition of 1st order is shown with the characteristic scale of the scheme of Fig. 3

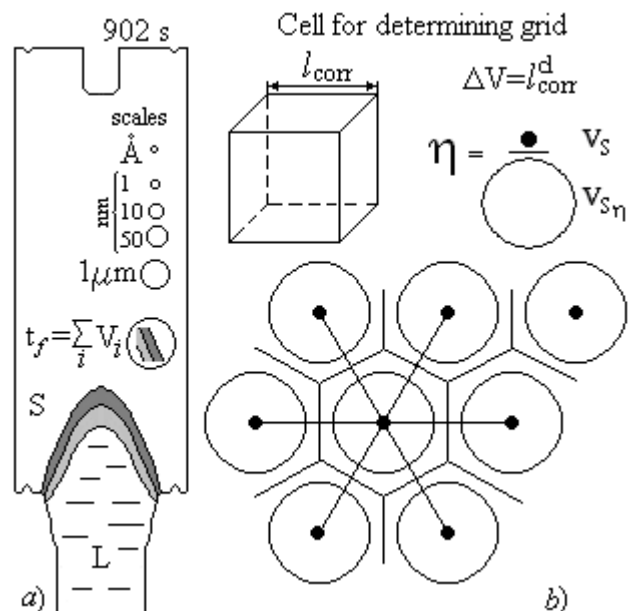


Fig. 3 The casting structures are obtained in phase transition of 1st order (solidification) [5]: a) Numerical experiment: technological solidification of a cylindrical cast at 902 s, graphically represented by the geometry of the solidification zone (front) - between the liquid (L) and the solid (S) phases. Scales Å, nm, 1 μm. t_f - local time of solidification. V_i - chosen local volume for description of structure formation; b) Cell for determining grid - l_{corr} for V_i , ΔV_i - changing the volume V_i from melting

(solidification), d – direction of growth 1D, 2D or 3D, η – packing density coefficient, v_s – volume of atom, $v_{s\eta}$ – volume cell, Wigner-Zeitz cell and structure.

The technological system of foundry we introduced on the example by the machine – Gas counter-pressure casting method Fig. 4

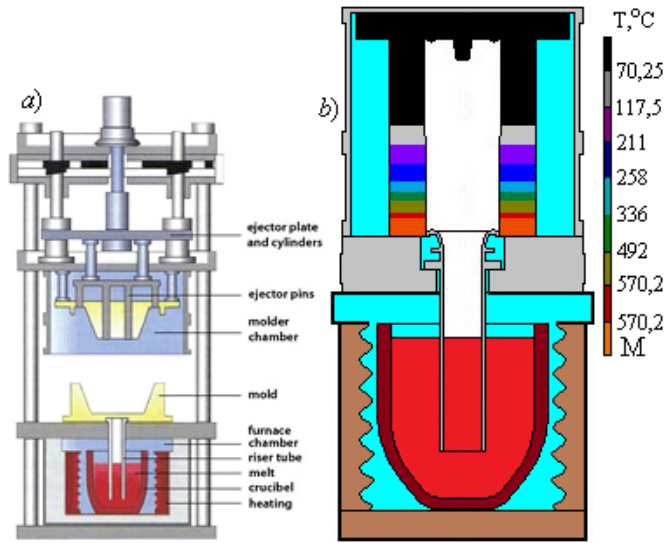


Fig. 4 Casting technology system - Gas counter-pressure casting machine: a) General appearance of the casting machine; b) Technology for producing counter-pressure cylindrical castings. The technological regime shown (see Fig.2 a) is obtain with initial temperature of the mould without taking into account the filling process.

The technological system (see Fig. 4) provides of macro-level to obtain the desired structure *average diameter of polycrystalline grains* [12]. The macro-parameters of the casting technology are **the overcooling of the melt** and **scattering of the latent heat of melting** [3, 5, 11, 12].

3. Mathematics in Foundry

It is well known, that the mathematics application in foundry is theoretical and applied thermodynamics [1, 2, 3]. The separation of each set of knowledge into science is achieved only by using mathematics, which definition is [3]: *Mathematics contains mathematical knowledge, foundation of mathematics, methodology of mathematics and philosophy of mathematics in a complex interconnectivity and continuous development.*

3.1 Mathematics in Thermodynamics and Foundry

The crystals are arranged in a solid state where the atoms or molecules are arranged in the form of a crystal lattice (structure). The crystals are obtained by a phase transition of first order by changing the aggregate state of the initial phase to the new solid phase. Bearer of the working properties of the castings is the crystalline structure, which is obtained in the phase transition of first order. Thermodynamics system in foundry is alloy (pure metal) (see Fig. 3 and Fig. 4). Casting is a fundamental branch of material science. It is known that the most advantageous technology for making castings with complex geometry is casting.

The description of the first-order phase transition is presented here in its historical development, i.e. the development of the classical theory of crystallization in atomistic approach. Table 1 presents: the description of thermodynamics; the theoretical description of nucleation like: thermodynamics and kinetics; crystal growth theory: Surface energy; Diffusion; Surface nucleation; Screw dislocation

Table 1: Phase transition in foundry: Liquid(L) $\leftrightarrow$ (S)Solid.

Liquid (L) $\xleftarrow{\text{phase transition of 1st order}}$ Solid (S)	
THERMODYNAMICS OF THE TRANSITION L $\leftrightarrow$ S	

$$G = H - TS, \text{ Gibbs free energy at } T_e \rightarrow G_L = G_S, \quad (1,1,2)$$

$$\Delta G = \Delta H - T\Delta S; \text{ and } \Delta G = G_L - G_S, \Delta H = H_L - H_S, \Delta S = S_L - S_S, \quad (1,3,4,5,6)$$

$$\Delta G = 0 \text{ is equilibrium at } T_e \Rightarrow \Delta H = T_e \Delta S, \quad (1,7)$$

$$\Delta G = \Delta H \Delta T / T_e, \text{ and } \Delta T = T_e - T, \quad (1,8,9)$$

$$\Delta G = \Delta S \Delta T \text{ for melt growth,} \quad (1,10)$$

$$\Delta G = RT \ln(S_R) \text{ growth depend to supersaturation ratio } S_R. \quad (1,11)$$

In foundry the basic thermodynamics system is material from two phases; G – Gibbs's free energy of the system; H – enthalpy; S – entropy; T – temperature; $T_e = T_L = T_S$ – equilibrium temperature; $T_e - T$ – supercooling; Δ – change of G, H, S; R – gas constant.

NUCLEATION – IMPORTANT PHENOMENON IN CRYSTAL GROWTH

$$\Delta G = 4\pi r^2 \sigma - \frac{4}{3}\pi r^3 \Delta G_v; \quad r^* = \frac{2\sigma}{\Delta G_v}, \quad \Delta G^* = \frac{16\pi\sigma^3}{3\Delta G_v^2} \quad (1,12,13,14)$$

$$\Delta G^* = \frac{16\pi\sigma^3 \Omega^2}{3(kT \ln S_R)}, \text{ Gibbs - Tomson equation} \quad (1,15)$$

$$J = J_0 \exp\left[-\frac{\Delta G^*}{kT}\right], J = J_0 \exp\left[\frac{16\pi\sigma^3 \Omega^2}{3(kT \ln S_R)}\right], S_{R/Cri} = \exp\left[\frac{16\pi\sigma^3 \Omega^2}{3k^3 T^3 \ln J_0}\right], \quad (1,16,17)$$

where ΔG_v – change the Gibbs free energy of nucleus volume of new phase (L or S); r – nucleus radius; r^* , ΔG^* – critical parameters; σ – surface energy; Ω – atomic (molecular) volume; J – nucleation rate per unit volume; J_0 – is the total number of particles in the new phase; $S_{R/Cri}$ – critical supersaturation ratio; k is Boltzmann's constant.

CRYSTALS GROWTH THEORY

1. **Surface energy theory** is on the based to thermodynamics equilibrium state with minimal total surface energy for given volume. There is contradiction theory-experiment: supersaturation and growth sides of crystal. At high supersaturation the growth is not uniformly of all directions and only of some sides.

2. **Diffusion theory** is on the base that there is a concentration gradient in the vicinity of the growing surface

$$\frac{dm}{dt} = \frac{D}{\delta} A(C - C_0) \quad (1,18)$$

where dm/dt is the rate the mass deposited on the crystal surface with area A ; D – diffusion coefficient; δ – thickness layer adjacent to the crystal surface; C and C_0 – actual and equilibrium concentration.

3. **Surface nucleation theory** is developed by Kossel [18], Stranski [19], Volmer [21], and Kaishev [23] (model KSVK): crystal growth on the surface with inhomogenities of the type terrace, ledge and kink; guess that the growth is discontinues process of absorption of the material layer by layer on the crystal surface. The arriving atoms (molecules) do not get directly into the grid, but they migrate over the surface in a random walk process and finally get absorbed on these sites, where its energy is a minimum. Migration distance x_s is

$$x_s^2 = D_s \tau_s, \text{ where } x_s \approx a[3\phi/2kT] \quad (1,19,20)$$

where D_s – coefficient of diffusion; τ_s – life time of the absorbed particle on the crystal surface; ϕ is the nearest interaction parameter. Migrate atoms create diffuse flow at the surface of the growing crystal, and they are called adatoms. Migrate atoms create diffuse flow at the surface of the growing crystal, and they are called adatoms. For adsorption of adatoms on the crystal surface is need description of interaction between one adatom and elements of surface relief: one adatom at kink site have three chemical bonds for six first neighbor's atoms from of the crystal lattice surface; adatom and ledge have two chemical bonds; adatom and terrace have one chemical bond. Barton-Cabrera-Frank model (BCF) [22] gives: 1. the rate of diffusion flow of migrate adatoms V_{ST} : distant migration step is much higher than distant between two kinks (or middle migration distance is much higher than the mean distance between two adjacent kinks); 2. When the movement step covers the whole surface completely, further growth is only possible by creating a two-dimensional nucleus circle with a radius r and a height h with the necessary energy change ΔG_{td} . According to Volmer [21], this is possible due to heat fluctuations; 3. The growth rate of a single side is generally controlled by the degree of germ formation and the rate of step advancement $R_{J_{td}}^{V_{ST}}$

$$V_{ST} = 2S_{x_s} x_s \gamma \exp(-W/kT), \quad (1,21)$$

$$\Delta G_{td} = 2\pi r h \gamma - \pi \tau^2 h \Delta G_v, \quad \Delta G_{td}^* = 2\pi h \gamma - \pi \tau^2 h \Delta G_v, \quad (1,22,23)$$

$$J_{td} = C_i \exp\left[-\pi h \gamma^2 \Omega / k^2 T^2 \ln S_{x_s}\right] \quad (1,24)$$

$$S'_{x_s/Cri} = \exp\left[\pi h \gamma^2 \Omega / k^2 T^2 \ln C_i\right] \quad (1,25)$$

$$R_J^V = h J_{td}^{1/3} V_{ST}^{2/3}, \quad (1,26)$$

where γ is a frequency factor in (1,21) and the edge free energy in (1,22

and 23); W is the **total** evaporation energy; S_{x_s} is supersaturation for the mean migration distance x_s , and index cri is for critical supersaturation; C_l – concentration of liquid.

4. Burton, Cabrera and Frank [23] (BCF model) **screw dislocation theory**: on the surface of the crystal in the dislocation point a screw component with a height of the Burger vector projection acts as a continuous source of steps; the step provided by the screw dislocation is fixed at the point of displacement; growth is only by rotation around the point of dislocation, like the inner parts of the tread moving faster than the outer parts of the tread. This mechanism can provide a relation between the rate of growth R and the relative supersaturation s which are expressed with the equations

$$R = C(s^2 / s_1) \tanh(s_1 / s), \quad (1,27)$$

$$s_1 = 19 / \Omega / 2kT x_s; \quad C = D_s \cap_{se} \beta \Omega / x_s^2,$$

where s – relative supersaturation; s_1 – a const for BCF model; $\cap_{se}$ – equilibrium concentration of growth units on surface; β – retardation factor; Ω – volume of the growth unit. The variation R with supersaturation thus depends on two parameters, C which determines the absolute value of growth rate and s_1 which determines actual growth rate. The BCF model predicts nucleation at edge dislocation predicts that the growth rate is proportional ($\propto$) to the square of the supersaturation for low supersaturation if $s \ll s_1 \Rightarrow R \propto s^2$ and changing to a linear dependence at higher supersaturations if $s \gg s_1 \Rightarrow R \propto s$.

Crystal growth in casting methodology – atomistic approach

1. Thermodynamics – thermodynamic driving force and work of nucleation.
2. Kinetics – nucleation rate and supersaturation number.

MACROSCOPIC LEVEL – SOLIDIFICATION [5]

1. **Heat Conductivity analytical solution**: 1.1 1D Stephan's problems; 1.2 1D Stephan-Schwartz problems;
2. **Numerical Solidification's Problems**: 2.1 1D Stephan's problems and 1D Stephan-Schwartz problems; 2.2 3D Stephan's problems and **the most important 3D Stephan-Schwartz problem**; 2.3 Numerical Methods: 2.3.1 Finite differentials method; 2.3.2 Finite elements method; 2.3.3 Boundary elements method.

Chemical bond short history introduction on the base table 7 page 199 in [13]: Mendeleev (1871) Eight as a maximum valence rule and the sum of the hydrogen and oxygen valences for higher types; Abegg (1904) Electrochemical interpretation of Mendeleev's rule of eight in terms of electron gain and loss; Thomson: (1904, 1907) Concept of chemical periodicity in terms of recurring outer electron configurations. Rule of eight as striving for completion of stable rare gas shells; Kossel (1916) Extension of ionic model. Eight as a maximum valence rule for polar compounds only; Lewis (1916) Continuity of bond type and electron pair bonding mechanism for octet completion; Langmuir (1919-1921) Elaboration and popularization of the Lewis model. Mathematical formulation of the octet rule.

As it is known, Kossel offers a kinetic theory of crystal growth [18] and Stranski offers the same model [19]. At their meeting at the suggestion of the Stranski model is a well-known Kossel-Stranski model. The 1930s saw the publishing of several important articles which Stranski co-authored with Kaishev [20, 23] and Krastanov [30], which is called Stranski-Krastanov's growth mechanism. Stranski [28] and Kaishev [23] have developed the method of average separation work, a molecular kinetic method, which has played a role in the development of the theory of crystal growth and growth. Kaishev and Stranski create: the model of the crystalline growth (layered crystalline growth); have merit clarifying the relationship between the two-dimensional germ formation and spiral growth of the crystals. Kaishev summarizes Wulff's theorem of the equilibrium crystal's form, Kaishev summarizes Wulff's theorem about the equilibrium shape of the crystal formed on a foreign substrate (Wulff-Kaishev's rule); Develops thermodynamics and kinetics of electro-crystallization and electrolyte nucleation. Application the Kossel-Stranski mechanism is [17].

Nucleation. Kashchiev's book [25] presents at the same time an introduction to the theory of nucleation; the new results, their role and the interaction of the new results with the full theory of crystalline growth; the directions of the development of the complete theory. Thermodynamics and kinetics are directed to saturation (driving force), nucleus size dependence and work of

nucleation. Regular spiral growth and known mechanisms of crystal growth are considered. Regular layered, spiral growth and known mechanisms of crystal growth are considered. A great potential for the application of the results in [25] to describe the first-order phase transition in the foundry methodologically is: the theorem of nucleation; and the basic kinetic equation of the formation of new phases for variable saturation. **Epitaxy.** Markov's book [26] considers in four parts the nucleation at obtaining of thin films in epitaxial growth, on the base of equilibrium between crystal and ambient phase, nucleation and crystal growth. The crystal growth mechanisms are examined, and the barrier effects on crystal growth mechanisms and on morphology analysis of the growing crystal surface are also considered. The mechanisms of Frank and van der Merwe and Stranski-Krastanov are discussed. The Mechanism of Stranski-Krastanov is the formation of several complete monolayers followed by the growth of isolated 3D islands and is well known to all epitaxial growth researchers. Barrier effects reporting require rewriting of the nucleation theory. An atom in a barrier effect like Ehrlich-Schwoebel has less close neighbors, which is important for morphology of surface growth. **Morphology.** The morphology of growing surface is part of the crystal growing. In [14] is presented graphical method generalized by general theorem. Has developed a new model of interaction between an internal structure and the morphology of a growing crystal surface [15]. In work [16] is study the growth and the morphology of Study of growth and morphology of precious stones.

An important moment for the foundry (but also for material science) is the natural boldness between the works of Balevski [6] and Borisov [7]. By definition [6] – By definition [6] – Metal science is the science of the relationships between structure and properties, as well as the influence that thermal, mechanical and other impacts have on the structure, and hence on the properties of metals and alloys. Metal science as a science emerges in the second half of the 19th century, originated in physics, metal physics, and so on. The introductory first part is Theory of Metals and Alloys: electronic structure of atoms; interatomic connections; crystal structure of metals; crystallization; physical - properties and methods of measurement; due to the engineering direction of [6]: deformation (elastic and plastic), mechanical properties and tests. These rigorous scientific terms clearly show the required minimum number of scientific fields in metal science, and only by the engineering need it is further clarified that the scientific ideas in [13] are not only in the theory of metal science but also in the theory of all **material science**. Изключително важен момент е: за описание свойствата на металите е създадена квантовата механика; използва се във фундаментални изследвания на физиката и техниката, които вече са съвпаднали. An extremely important point is: *quantum mechanics has been created to describe the properties of metals*; used in fundamental studies of physics and technology that have already coincided. The full theory of crystalline growth covers applications such as semiconductor materials and structures for nanoelectronics [...].

In [7] the introduction of solid state physics is based on quantum chemistry, i.e. the application of quantum mechanics for explanation of the chemical connection (electromagnetic interaction see Fig. 2). The interaction of the electron (atomic core) is coulomb and the state of the electron in the atom lies as a solution to Schrödinger's amplitude wave equation. Types of solid bodies according to the type of interatomic connections [7]: ionic crystals - crystalline lattice consists of oppositely charged ions; valent crystals - the atoms are connected in a crystal lattice with a covalent (homoeopolar) bond; metals - a crystal lattice is made up of positive ions, the repulsive forces between them being equalized by the free electrons; molecular crystals - the lattice is made up of individual molecules or atoms interconnected with intermolecular (van der Waals) forces. Metal alloys are the simplest chemical compounds - solutions. The crystal lattices of the alloys according to the size of the atoms are: solid substitution solutions; solid solutions of deployment. It can be said that work [7] binds work [6] with

quantum mechanics. Work [6] and [7] are expanded by [9] for electron theory in metals.

Full mathematics is called upon to create new purely mathematical theories. The new theories are evolving because Gödel's theorems of "incompleteness" clearly show that there is no complete mathematical theory. The history of mathematics shows the need for the development of pure mathematics, but it is challenging to suggest the assessment of the development of the necessary, for example, a "new mathematical field".

A scale of $1\mu\text{m}$ is a macro-scale. Scale for nm or Å requires modern methodologies based on [8, 9, and 10]. Generalized this is the mathematics, the theoretical and the mathematical physics presented in Fig. 5

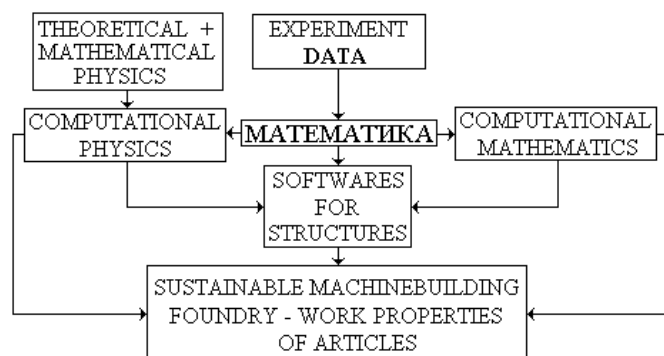


Fig. 5 Scheme - Full mathematics is needed in Micro-Foundry and Industry 4.0.

4. Conclusion

Mathematics is a powerful tool for research. Mathematics is needed in public development, for example "virtual factories", apart from technological, legal relations between companies, based on new experimental data, evaluations are also made for research ideas for development from "artificial intelligence". Hence Industry Change 4.0: "factories without people", and people naturally need life-long education.

5. References

1. S. Bushev, Knowledge transfer Industry 4, International Scientific Journal "INDUSTRY 4.0", No 4, p.51-54, Year I, ISSUE 1/2016
2. Ch. Kittel, W. Knight, M. Ruderman, Mechanics, Berkeley Physics Course, v. I, "Nauka", Moscow, 1975. (In Russian)
3. S. Bushev, Industrial mathematics – phase transitions, scattering, structures, International Scientific Journal "INOVATIONS", p.57-62 Year V, ISSUE 2/2017, Sofia.
4. K. Schwab, The Fourth Industrial Revolution, "Hermes", 2016, ISBN 978-954-26-1630-6 (In Bulgarian)
5. S. Bushev, Theoretical model of structureformation in die casting, XXII International scientific technical conference "FOUNDRY 2015", 16-17.04.2015, Pleven, Bulgaria, Year XXIII, ISSUE 3(166), April 1015, p.60-63, ISSN: 1310-3946 (In Bulgarian)
6. A. Balevski, Metaloznanie, „Tehnika“, Sofia, 1962. (In Bulgarian)
7. M. Borisov, K. Marinova, Uvod vav fizikata na tvardoto tialo, I chast, „Nauka i izkustvo“, Sofia, 1977. (In Bulgarian)
8. E. Pavarini, E. Koch, F. Anders, and M. Jarrell (Eds.) Correlated Electrons: From Models to Materials, Autumn School organized by the Forschungszentrum Jülich and the German

Research School for Simulation Sciences, 3 – 7 September, 2012. ISBN 978-3-89336-796-2

9. U. Mizutani, Introduction to the electron theory of metals, Cambridge University Press, 2003, ISBN 0 511 01244 6

10. U. Landman, Materials by numbers: Computations as tools of discovery, PNAS, May 10, 2005, vol. 102, no. 19, 6671–6678

11. S. Bushev, Multyscales evaluation structure formation – casting, Proceed. Forth national conference with international participation "Materials science, hydro- and aerodynamics and national security'2014", p.19-23, 23-24, October, 2014, Sofia, Bulgaria

12. S. M. Bushev, Controllability problems of crystallization process in casting, Thesis of PhD, TU, Sofia, 1993.

13. W. B. Jensen, Abegg, Lewis, Langmuir, and the Octet Rule, Journal of chemical education, Volume 61, Num. 3, March, 1984.

14. P. Terpstra, W. J. van Weerden, Graphical methods for the determination of reticular densities and lattice parameters, www.minsocam.org/ammin/AM19/AM19_531.pdf

15. E. Dowty, Crystal structure and crystal growth: I. The internal structure on morphology, American Mineralogist, Volume 61, pages 448-459, 1976.

16. I. Sunagava, Growth and morphology of crystals, *Forma*, **14**, 147–166, 1999. Reprinted with permission from Mathematical Sciences, No 358, 1993, (in Japanese)

17. G. Wranglén, Bravais' and Kossel-Stranki's Theories of Homopolar Crystals and their Applications to Elements, Acta Chemica Scandinavica, **9** (1955) 661-676.

18. W. Kossel, Nachr. Ges. Wiss. Göttingen, Math. Phys. K1 11A (1927) 135.

19. I. N. Stranski, Z. Phys. Chem., 136 (1928) 259.

20. I. N. Stranski, and R. Kaischew, 2. Phys. Chem., (B) 26 (1934) 31

21. M. Volmer, Die Kinetik der Phasenbildung (Steinkopff, Dresden, 1939).

22. W. K. Burton, N. Cabrera, F. C. Frank, Phil. Trans. Roy. Soc., A243 (1951) 299.

23. R. Kaishev, Selected Works, Publishing House of the Bulgarian Academy of Sciences, Sofia, 1980. (In Bulgarian)

24. M. C. Flemings, Solidification processing, Peace, Moscow, 1977. (In Russian)

25. D. Kashchiev, Nucleation: basic theory and application, Butterworth-Heinemann, Oxford, 2000. ISBN 0 7506 4682 9

26. I. Markov, Crystal growth for beginners: fundamentals of nucleation, crystal growth and epitaxy, World Scientific, Singapore, 2004.

27. Crystal growth: Theory and techniques, www.shodganga.inflibnet.ac.in/bitstream/10603/.../08_chapter1.pdf

28. I. Stranski, www.revolvy.co/main/index.php?s=Ivan%20Stranski

29. https://bg.wikipedia.org/wiki/Ростислав_Кашиев

30. Stranski, Ivan N.; Krastanow, Lubomir (1938). "Zur Theorie der orientierten Ausscheidung von Ionenkristallen aufeinander". Abhandlungen der Mathematisch-Naturwissenschaftlichen Klasse IIb. Akademie der Wissenschaften Wien. **146**: 797–810

31. A. Popov, Semiconductor materials and structures for nanoelectronics, University Publishing house "St. Kliment Ohridski", Sofia, 2007. ISBN 978-954-07-2539-0 (In Bulgarian)

THE POSSIBLE IMPLICATIONS OF TAX REFORM IN RUSSIA

Prof. Dr. Elena Yrevna Sidorova, National University of Science and Technology MISiS
ejsidorova@yandex.ru

Abstract: The upcoming three-year period is marked for Russian tax system as a period of crucial reforms and restructuring. Computational-analytical method was used as the main one. Possible fiscal consequences for the country economy were calculated on the basis of three options of the proposed changes in tax rates. The study was conducted on the example of four taxes: value added tax, corporate income tax, personal income tax and insurance premiums. Based on the calculations the possible consequences of changes in tax rates are determined taking into account possible changes in consumer behavior, systems approach to the investigation of the tax system, and the appearance of the feedback loop effect. **Keywords:** tax reform, tax, system approach, consumer behavior, feedback loop effect.

KEYWORDS: TAX REFORM, TAX SYSTEM APPROACH, CONSUMER BEHAVIOR, THE EFFECT OF THE FEEDBACK LOOP.

1. Introduction

The upcoming three-year period is marked for the Russian tax system as a period of crucial reforms and restructuring. By 2019 the national tax reform of value-added tax (hereinafter VAT) and insurance premiums is expected to be completed. Three options of the proposed changes in tax rates will be considered in this article, as well as possible fiscal consequences for the country economy will be calculated.

Option 1. Compulsory payments to the social insurance system at the rate of 22% with levying from the entire payroll (cancellation of "thresholds") with an increase of the VAT rate to 20% and abolition of preferential rates in the 10% (hereinafter "option 1");

Option 2. Aggregate payments to the social insurance system at a rate of 21% with levying from the entire payroll (cancellation of "thresholds") with VAT 21% and cancellation of preferential rates in the 10% change (hereinafter "option 2");

Option 3. Aggregate payments to the social insurance system at a rate of 21% with levying from the entire payroll (cancellation of "thresholds") with VAT 20%, while maintaining preferential rates, applying of a trade fee in all regions and raising the personal income tax up to 15% (hereinafter "option 3").

Purpose of the article: to assess the fiscal effect of these three options for tax reform conducted until 2019.

2. Results and Discussion

From the standpoint of the need for a theoretical justification for the chosen forecasting methodology, the authors of this study used the following starting points.

1. When choosing the industries for the study, the size of employees' wages was taken into account.

2. The organizations of the researched industries are not payers of the trade fee, in this connection this fiscal payment was excluded from the calculation of the effectiveness of the third option of the tax reform.

3. During the calculations, the analyzed indicators were indexed for the inflation rate planned for 2017 - 4%.

4. Evaluation of tax reform options effectiveness was estimated by the computational-analytical method, actively used in conditions of multi-optional planned events and insufficient verifiability of the information base.

Thus, according to option 1, due to the payments to the Pension Fund of Russia (PFR), Social Insurance Fund (SIF), Federal Compulsory Medical Insurance Fund (FCMIF), the total volume of falling out revenues of the six selected industries will account 19.27 billion euro, due to the corporate income tax- 3.86 billion euro; While the volume of additional revenues from the value-added tax, taking into account the changes proposed in option 1, will amount 55.56 billion euro.

Consequently, the total amount of budget losses will amount up to 17.56 billion euro or 16.4% of the tax revenues for the sectors selected.

The conducted calculations of the option 2 demonstrated that the total volume of falling out revenues for the studied economy industries as a result of the changes in the tariffs of insurance premiums of PFR, SIF, FCMIF would be 21.68 billion euro, corporate income tax - 4.34 billion euro; while the volume of

additional revenues from the value-added tax would amount up to 7.15 billion euro. Thus, the total amount of budget losses would account 18.87 billion euro or 17.6% of the tax revenue for the industries selected.

The assessment of the cumulative economic effect of option 3 allowed to determine that:

- The amount of the falling out income for the six industries analyzed due to the payments to PFR, SIF, FCMIF will be 21.68 billion euro;

- The drop in income from corporate income tax, formed because of the increase in the costs accepted for calculating this tax in the form of insurance premiums, will be up to 4.34 billion euro;

- The volume of additional revenues from the value-added tax will account 0.934 billion euro;

- The volume of additional income from the income tax will be 6.022 billion euro.

Consequently, the total budget loss of option 3 will account 19.06 million euro or 17.75% of the tax revenue for the industries selected. The conducted calculations showed that option 2 would lead to the biggest loss of the budget.

The general trend of changes in tax rates leads to the conclusion: prevalence of indirect taxation ultimately increases the tax burden on the end user. During the first phase of implementation the increase of indirect taxes has a positive impact on producers, releasing free cash flows necessary for production development, making the country economy more attractive for investors.

During tax reforms, two rules of the systems management theory must be remembered:

1. Taxes and taxation is a system, the essence of which is in the fact that it can sustain itself and function as a single unit, as a result, of its parts interaction;

2. There is the effect of the feedback loop, which can be both positive and negative.

In the context of the three options, it might be concluded that it is balancing feedback. The mechanism of balancing feedback adjusts the difference between the actual and the desired state of the system. After two years of the test application, the revenues will be the same as if the tax rates are not changed at all. It will just change the source of tax payments: after implementation of the tax reform, tax burden will increase for the end user or the population of the country but the main goal - economic development - will not be achieved, while the way of people's thinking will be different.

The behavior of Russian end user can be classified as traditional, and the behavior of the taxpayer - can be classified as optimizing. Due to the income reduction (an increase of personal income tax rate by 2%) and an increase of prices (the application of a trade charge and the increase of VAT up to 20-21%), there will appear a common habit of increased money saving. It will lead to further growth of market competition and difficulties in sales markets. Negative consequences will also be connected with low efficiency of marketing tools applied by Russian producers, in compare with Western companies, as well as due to the short-term period of habit formation (3 months). Moreover, after 8-10 months the habits are transformed into a routine (used by R. Nelson and S. Winter) - established practice, the established order of activities.

It should be noticed, that the practice of transferring the tax burden from production to consumption is a general trend for over the past 10-15 years. However, in contrast to Russia, the tax

maneuver includes VAT and corporate income taxes, but not the insurance premiums, which are the main pension systems worldwide. For instance, corporate income tax rate is constantly decreasing in Switzerland during last years. Typical rates of corporate income tax in different cantons (regions) of Switzerland varies from 8 to 10.5%¹, that makes it highly competitive in compare with other European countries. In many OECD countries, personal and corporate tax rates are reduced, while the taxation base and the contributions to social security system are increased. At the same time, there was a general tendency to VAT rates increase since 2006, and it allowed obtaining certain positive effects. However, all OECD countries, excluding Australia and New Zealand, levied compulsory social insurance contributions on labor incomes in which there is a general upward trend².

3. Conclusion

According to the above written it can be concluded: changes in tax rates will influence 97.7% of the working population in the country and it will change their behavior model. The new behavior model will reduce the capacity of the market, reducing the consumption of domestic products of low quality and high price, replacing them with cheaper foreign counterparts. These changes will eventually lead to deprivation of Russian companies of a significant number of its customers.

Moreover the temporary effect of VAT rate increase (the first option of the budget revenue growth 5.56 billion euro, the second - 7.15 billion euro, the third – 0.934 billion euro) will be fully or partially lost due to lower level of consumption and market contraction.

Thus, we believe that the transfer of the tax burden from production to consumption is premature, unjustified, and ineffective. Still the process is inevitable, so the change in tax rates should be gradual. For instance, an increase or decrease of interest rates by 1-2%, choice of one or two taxes a year as the object of changes, and such changes should be held every two years in order to determine the effect of the feedback loop from the accepted changes and adjust further action.

4. References

1. Improvement the methods of tax regulation mechanism effectiveness assessment in the Russian Federation In Russian) // ЕКОНОМІЧНИЙ ЧАСОПИС-XXI № 11-12, 2015 С.47-51.
2. Weber M. Selected works. - Moscow: Progress, 1990.
3. Sidorova E. J., Conniston D. V. The Economic substance of tax regulation // Economy and society, No. 1, 2014.
4. Hodgson J. Habits, rules and economic behavior // Issues of Economics. - 2000. - No. 1.
5. International corporate tax: Investment in Switzerland, KPMG, Edition 2012. – pp. 77.
6. Å. Johansson, C. Heady, J. Arnold, B. Brys and L. Vartia Tax and economic growth // Economics department working paper, NO.620, ECO/WKP(2008)28, - 85 pp.

¹ INTERNATIONAL CORPORATE TAX: Investment in Switzerland, KPMG, Edition 2012. – pp. 77.

² Å. Johansson, C. Heady, J. Arnold, B. Brys and L. Vartia TAX AND ECONOMIC GROWTH // ECONOMICS DEPARTMENT WORKING PAPER, NO.620, ECO/WKP(2008)28, - 85 pp.

SCIENTIFIC-METHODOLOGICAL PROVISIONS OF FORMATION OF A VIRTUAL SEGMENT OF THE INFORMATION MARKET

НАУЧНО-МЕТОДОЛОГИЧЕСКИЕ ПОЛОЖЕНИЯ ФОРМИРОВАНИЯ ВИРТУАЛЬНОГО СЕГМЕНТА ИНФОРМАЦИОННОГО РИНКА

Doctor of Economic Sciences, Professor, Zhavoronkova G.,
PhD (Economics), Associate Professor, Zhavoronkov V.
National Aviation University, Kyiv, Ukraine.
PhD (Economics), Associate Professor Melnyk L.,
National University of horticulture, Uman, Ukraine.
zhavor@ukr.net

Abstract: *Gradually in the world formed a unified information space. There is something that is called "global virtualization". Author determines virtuality as a phenomenon, which represents the ability to generate creative reality. Virtual market is a market of goods and services that exists on the basis of telecommunication and information capabilities of the global Internet, basic elements of which are: free market access for all comers; equal rights and voluntary participation of all participants; the possible influence of participants on what is happening in the market. Under e-business, we understand the organization or person, in which basic business processes and internal and external communications are made and provided by electronic technology. Today it is not established neither theoretical nor methodological principles of virtual corporations as well as sufficient experience in their creation. The attention of practitioners devoted to the peculiarities of the creation of enterprises with the virtual principles of the organization. The study of trends in the development of the Internet and the possibilities of its application in economic activity also revealed that along with the structural and quantitative changes in this sphere occur the social and economic impacts of telecommunications development.*

KEYWORDS: INFORMATION MARKET, VIRTUAL SEGMENT, GLOBALIZATION, VIRTUAL, MARKET, CORPORATION

1. Introduction

Modern feature of the development of civilization in the XXI century, undoubtedly, the globalization of companies. Informational globalization is a unique phenomenon in the modern economic and social life all sta. Its essence is determined by the information dependence of agents in this environment mediated by new technologies, flow of information, the formation of an increasing number of sources and channels of information. Information globalization has significantly contributed to progressive changes in the economy and society as a whole.

Thus, the process of globalization is accompanied by the avalanche spreading information flows, so gradually in the world formed a unified information space. There is something that is called "global virtualization". So today in the world of Informatization, the term "virtual" is the key. Already talking about the emergence of virtual companies or an Internet civilization.

Information nature of the present stage of civilization evolution determines the situation when no country without an effective entry into the world information space can't successfully compete in the sectors of high and medium technology not only on external but also on the domestic market. Today it is not enough to link the development of the information society only with the solution of problems transmission, access, processing and storage of information or information products. Strategic planning processes of producing information in the form of new knowledge and the mass production of information technologies, which determine the modern condition of the productive apparatus and social-economic development of the country.

In contrast to the actual reality, which reflects the integrity, stability and completeness, virtual reality is a source of difference and diversity. Thus, virtuality is considered a phenomenon that is immanent in the very structure of being, represents the ability to generate creative reality. At the same time in different subsystems of society are "parallel worlds", in which operate the virtual analogues of real mechanisms of reproduction of society: economic cycles, political action, legal discourse of laws, the actions themselves on the Internet and the like. The process of replacement by using information computer technologies of real space as a locus of social reproduction of the virtual space, Bühl A. virtual calls [1].

2. Scientific definition and composition space virtualization

From a scientific point of view, the space of virtualization include: virtual market, the virtual Corporation (enterprise), and virtual reality.

Virtual market is a market of goods and services that exists on the basis of telecommunication and information capabilities of the global Internet, basic elements of which are: free market access for all comers; the possible influence of participants on what is happening in the market; equal to the degree of awareness of the participants. Virtual market operates continuously in real time, covers the whole world and enables a variety of virtual operations.

The virtual environment opens for business new opportunities in the economic sphere, including through electronic Commerce. Occurs as the creation of new enterprises, focused only on e-Commerce and traditional businesses use electronic Commerce in their practice.

The virtual Corporation is a temporary form of voluntary integration of multiple, usually independent partners (companies, institutions, individuals), which is due to the system optimization advantages of production provides the advantage of customers. In a different interpretation under the virtual Corporation refers to marginesie flexible enterprise, which is temporarily created and the main purpose is to obtain benefits through the expansion of the range of goods and services [2]. In other works a virtual enterprise to define such terms – "world enterprises" [3], "infinite enterprise" [4] and the "extended enterprise" [5].

The virtual Corporation, like other companies operating in the market are General purpose, namely, profit and competitive advantage in the market. Feature of achieving this goal is that the virtual enterprise in its activity oriented to the whole market, all the competitive environment and not become attached to his particular segment, and work on the scheme (Fig. 1). A prerequisite for the creation of a virtual Corporation is the receipt of a market order. For the order creates a virtual network, which through its core competencies provides the virtual enterprise with the necessary resources and determine their capabilities (personnel, raw materials, management structure, financial and other resources, know-how, expertise and rights in a particular industry). With the help of electronic means are

provided information and communication services and executed a market order. For subsequent orders, on the basis of existing entrepreneurial pool creates new virtual network.

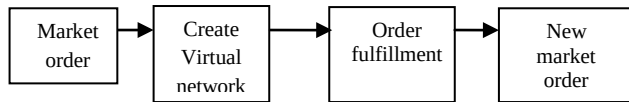


Figure 1. The scheme of virtual Corporation

Virtual corporations have significant advantages in comparison with other organizational forms of enterprises. The most important thing is that they can choose and use the best global resources, expertise and opportunities with the lowest variable costs. These features and their specific organizational structure allows you to become a leader in a competitive environment due to competitive advantages, namely the speed of execution of market order; the decrease in the level of total expenditure; the possibility of choosing partners and entering new markets; the use of information from all over the world.

Virtual corporations have institutional characteristics that distinguish them from traditional forms of integration (table. 1).

Table 1

The differences between traditional and virtual corporations

Form integration	The main goal	Traditional signs	Differences from virtual Corporation
Project organization	Individual projects to address complex and risky task	Interim organizational structure. Cooperation of various departments and hierarchical levels of the organization	The restriction of certain areas of knowledge that dictates the market system. The lack of strategic management concept
Intra-corporate organizational structure	Pseudocumene structure to improve performance in the solution of separate tasks	Pseudocumene units. Self-organization. Internally the brand enterprise	Integration is not a temporary network. Competence does not coordinate with a third party
"Keiretsu" (Japan)	The merger of trading, several industrial companies and one major Bank (insurance company)	The Association is based on cultural ties. Close contacts with politicians and the administration. The use of a synergistic effect to gain market	Integration for a certain period. Low flexibility in changing partners. Complex financial linkages (cross-holding)
Strategic Alliance or joint venture	Economic integration to benefit in time, cost, know-how	Long-term cooperation with mutual participation. The use of a common production process	Long-term integration with partners. As a rule, mutual participation in the capital. Hard links
Outsourcing firm	The allocation and transfer of certain tasks to a third party	Focus on your own competencies. A contractual relationship. The individual phases of the production of goods	The classical approach to "make-buy". Contractual relationship with a partner. The transfer of production outside the enterprise
Multinational Corporation	Taking advantage of the global activities due to the scale of production (range)	The legal agreement between the companies. General economic policy	A legal unit for a long-term period. Stability of the partners. Weak market mobility

Virtual reality is the simulation of real processes of development and production in cyberspace, which is both a medium and a tool. Virtual reality as a tool allows you to intuitively build complex structures, and the environment gives the opportunity to abstract to a product, production building, workplaces, machines and equipment before they will really exist.

3. The virtual segment of the information market

The services offered by the Internet, there is a variety of. But there are six basic economic models virtual economy (information production): Retail model; Media model; Advisory model; Made-to-order model; Do-it-yourself model; Information services.

The market for Internet services are characterized by some characteristic features, namely:

economical: very low cost almost always possible to achieve maximum results; globality, that is, the General ability of the global network. There is also the concept of local markets for Internet services, under which we understand the body providers, Internet companies, e-business infrastructure and Internet users in a certain area. It is the nature of the placement, the circulation of information flows and use of information makes the market global; the rapid pace of development and changes, because the

market of Internet services is one of the most dynamic businesses. The number of WWW servers is increasing rapidly; free competition. Being highly profitable, the market of Internet services around the world is one of the most competitive; high technology, as they are, on the one hand, the basis for the further development of the world wide web, on the other hand, as a result, since introducing new ideas in new technical solutions require new technologies; high capacity of the market of Internet services, which is estimated as the amount is incomparable in width and in depth;

high growth services. In different countries depending on local conditions and the development of the market, the annual growth of Internet services ranges from 15 to 250% [6].

Subjects of the market of Internet services can be divided into three large and interrelated categories:

service providers – companies producing and selling Internet products and services for use or consumption;
users – individuals and legal entities who buy these products and services for use or consumption;
infrastructure, regulatory bodies and research institutions.

In the new EU strategy "Europe 2020" deserves attention in the context of our study, the category of "Plan for the development of digital technologies in Europe".

The purpose of this direction of development is the creation of a sustainable economy and social benefits by creating

a common digital market based on fast Internet and common applications.

E-business – e-business in Web developing rapidly. Today in its third stage of evolution of e-business that already focuses not on the provider and on the consumer and allows you to automate complex patterns of business relationships.

Under e-business we understand the organization or person, in which basic business processes and internal and external communications are implemented and provided by an electronic technology and which are focused on profit. Internet selling may not be the main characteristic of e-business that makes it different from ecommerce, ACET contributes to buying and selling on the Internet.

There are three main components of e-business: electronic document management; e-Commerce; the electronic payment system. P. Drucker in the emergence of the phenomenon of e-Commerce sees the most vivid manifestation of the impact of information technology. Today, in his opinion, worth talking about: "the explosive emergence of the Internet as a critical channel for global distribution of goods and services... which fundamentally changes the economy, markets, industrial structure, nature of products and services and their flows, values, behavior, and segmentation of consumers, jobs and labor markets" [7].

One of the types of e-business is electronic Commerce, which can be defined as the business processes for the sale, carried out between subjects with the help of information and telecommunication technologies to ensure the achievement of economic and financial objectives of the subjects as well as help reduce costs. When using new technologies, e-Commerce enterprise open new markets and get a number of additional advantages, namely:

- increases the efficiency of obtaining information;
- improving the quality of customer service;
- reduces the production cycle and sales;
- you receive the savings by reducing inventory;
- significantly reduced costs associated with the exchange of information; enterprises are becoming more open to customers;
- appears the ability to quickly and around the clock to inform partners and customers about products and services;
- allows you to create new sales channels like e-shop, there are new markets and consumers;
- increasing the competitiveness of;
- increases the value of companies for shareholders.

Category E-banking can be defined as a technology of remote banking service, which provides access to accounts and transactions at any time from any computer.

Today there are a number of models of electronic Commerce: electronic Department stores with a particular trademark; e-shop of the manufacturer; e-market intermediary firms; the electronic catalogue is the representation of a large amount of products from different manufacturers; an electronic auction; virtual community; manufacturers of systems of the technological chain of e-Commerce; consulting services; information brokers; research services.

The creation of national centre's of e-Commerce and their integration into the intergovernmental network will eliminate information barriers between producers and consumers of products and services, will provide conditions for the search of new markets in rapidly changing conditions, the structure of demand and supply, which will significantly stimulate the development of market infrastructure and create better conditions for the presence of domestic producers in regional and global markets for goods and services, and will also affect the development of small and medium-sized businesses.

In the era of the protracted revolution in Economics of the information business, the majority of analysts agree in opinion that it is necessary to take into account such principles of "survival" information company on the Internet:

- rate on income from online advertising;

full use of modern Internet technologies with information flows, including quality of aggregation of information materials and search engines, cross links, personalized content, sending automated reminders and notifications;

the development and cultivation of strong brands, which only can be formed a loyal and stable user base [8].

Thus, e-business is a strategic area of development for most business processes. For corporate projects started consistent and painstaking work in two aspects: on the one hand, to develop new horizons of the Internet business, and improving technology, but first and foremost, of management techniques Internet business systems. Therefore, to successfully compete today, you need to quickly and accurately performed via the global Internet network for the exchange of information between companies and States, to conduct virtual marketing, e-Commerce and generally e-business.

4. Legal regulation of the activities in the virtual space

In connection with the increase in the number of Internet users, the use of virtual technologies in government, banking, scientific, and educational institutions, especially with the advent of e-business has emerged the need for regulation of corresponding social relations at the legislative level. It should be noted that the main feature of the Internet is that in the global network no national boundaries, there is no Central governing body, which would be able to initiate legislation. This feature determines the specificity of law-making, the necessity of harmonization of national legislation with international regarding these relations. The most active group of users of information technologies in the world are private companies. The questions that interest them, – negotiating and concluding deals with legal power, with computer communications, that is using electronic document management systems (EDMS).

International legal harmonization in the regulation of the SED took place gradually, taking into account the needs of practice and differences in the legal systems of States. At the beginning of this process was developed by the UNCITRAL model law "On electronic trade". The basis for regulation was taken "functional equivalent approach", based on the analysis of goals and functions of the traditional requirements for the preparation of paper documents in order to determine how those purposes or functions can be achieved or performed through electronic Commerce techniques.

An attempt of considering the possible impact of Internet Commerce on the structure of interaction of market participants was carried out by the European Commission. in 2010, when was the document on the settlement of vertical restrictive agreements (HEU) in the EU, which was introduced a number of innovations, taking into account the development of the Internet [9]. One of the controversial points of the new document were the conditions under which restrictions on the Internet are eligible. In this context, there are a number of issues which require consideration, namely [10]:

- 1) outright ban on Internet sales. It is necessary to distinguish "active" and "passive" sales. Active sales are sales that are carried out against individual consumers, specific groups of consumers or consumers that pertain to specific areas. Passive sales are carried out in the case of the reaction of the distributor on the individual needs of the consumer;
- 2) a ban on Internet sales according to the territorial principle to protect the exclusive territories;
- 3) restrictions to Internet retailers;
- 4) the conditions imposed on Internet Commerce. For example: dual pricing, high quality requirements, encourage customers to attend exhibitions distributor, etc;
- 5) the minimum resale price.

Thus, in accordance with the new box exceptional measures for settlement of vertically restrictive agreements and

"Principles of leadership", the European Commission attempted to strike a balance between market participants, allowing consumers to effectively use Internet Commerce, and at the same time allowing suppliers to determine the optimal model of distribution and selection of distributors. From time to time the European Commission will provide additional clarification to the new rules, and the rules themselves will remain in force until 2022. However, the activity of subjects of information relations in the global computer network Internet requires further improvement of legal regulation. Relevant laws and regulations should take into account the achievements of international organizations in this field and, in particular, the EU.

5. Conclusions

So, the Internet is evolving and requires further consideration, research and legal clearance. Already the work on the Internet has become a context of production for many companies: it is the streamlining of programs, reference websites, catalogs, specialized and popular magazines, directions for significant information flows. There is no doubt that the network becomes an independent branch of the economy. At the same time, it is important to realize that the conditions for the formation of self-sufficient Internet economies that cannot influence the government. In the modern Internet companies its true global environment activities, their global competition. The last "offline" to strict national regulation, and the only way to avoid losses is the liberalization of info-communications. And it should be remembered that today no one country has the necessary resources to single-handedly do to capitalize on the global Internet.

Accelerated innovative development of information and computer technologies will allow to create new jobs and increase the level and quality of life of the population; align interregional disproportions; to ensure sustainable economic growth; to enter the international markets of information; to integrate into international organizations; to increase the flow of foreign investments; to accelerate economic reforms in Ukraine; to build the information society.

Today it is not established neither theoretical nor methodological principles of virtual corporations as well as sufficient experience in their creation. The attention of practitioners devoted to the peculiarities of the creation of enterprises with the virtual principles of the organization. In our opinion, the virtual enterprise must be established in domestic conditions as they can significantly affect the level of investment attractiveness of Ukraine.

The study of trends in the development of the Internet and the possibilities of its application in economic activity also revealed that along with the structural and quantitative changes in this sphere occur the social and economic impacts of telecommunications development, as a significant gap in this area can lead to the outflow of the most qualified personnel to other countries. However, all the advantages of the virtual market can and should be used by firms to improve their business relationships.

6. References

1. Bühl A. Die virtuelle Gesellschaft des 21. Jahrhunderts: sozialer Wandel im digitalen Zeitalter. Wiesbaden: Westdeutscher Verlag, 2000.
2. Khrushch N.A. Features create and manage virtual enterprises / Khrushch N. A. Donchenko T. V. // Bulletin of RSTU. Economy. – Rivne, 2002. – Vol. 2(15). – P. 406-411.
3. Wytrich, A. G. Virtualization as a possible way of development / Wytrich, A. G., Andres F. // Problems of theory and management practice. – 1999. – No. 5. – <http://www.ptpu.ru>.
4. Paturel R. creating a network of organizations of a new type / Paturel R. // Problems of the theory and practice of management. – 1997. – No. 3.
5. Tarasov V. Causes and characteristics of businesses of a new type / Tarasov V. // Problems of the theory and practice of management. – 1998. – No. 1.
6. Veretelnikova Y. O. the Internet Market In Ukraine – black box with many unknowns / Veretelnikova Y. O. // Marketing in Ukraine, 2001. – No. 3. – P. 6-9.
7. Drucker P. Beyond the Information Revolution / Drucker P. // The Atlantic Monthly, 1999. – V. 284. – № 4.
8. Mitilino S. E-business-incubators, or how to organize your own shopping site / Mitilino S. // Computer network /ITS, 2000. – No. 22.
9. Commission Regulation (EU) №330/2010 on the application of Article 101(3) of the Treaty on the Functioning of the European Union to categories of vertical agreements and concerted practices: [Electronic resource]: Electronic access: http://ec.europa.eu/competition/antitrust/legislation/guidelines_vertical_en.pdf
10. Shalashova M. E. E-Commerce in the EU: new forms of regulation of vertical restraints agreements and their impact on e-Commerce /Shalashova M. E. // Scientific works of DonNTU. Series: economic. Vol. 40-1. – Donetsk: DonNTU, 2011. – P. 206-212.

INTEGRATING OPEN DATA INTO COMPANIES' BUSINESS MODELS FOR FOSTERING DIGITAL TRANSFORMATION

Antonova A.¹, Yordanova S.²,
Sofia University, Bulgaria¹
University of National and World Economy, Bulgaria²
a_antonova@fmi.uni-sofia.bg
syordanova@unwe.bg

Abstract: Horizontal and vertical integration of companies within the value networks plays a substantial role for faster and wider implementation of Industry 4.0 and adoption of new digital business models. The policy for open data encourages companies to integrate more data flows coming from public sources into their operations. Thus, digital transformation of companies needs to reconsider the available public and open data flows and to improve their business models. The present paper aims to present and analyze how companies can integrate Open data in digital transformation process and new business models' adoption. The main elements of digital business models within Industry 4.0 and smart factories is introduced and discussed. Open data models and standards are analyzed and assessed as a source for value creation within companies. Finally, the paper identifies and discuss the main approaches for companies to implement open data into their business models.

Keywords: OPEN DATA, BUSINESS MODELS, INDUSTRY 4.0;

1. Introduction

Open Data (OD) and Open Government Data (OGD) became part of large national and international policy initiatives targeting to enforce public authorities to provide open access into public data. Open data became part of government efforts to promote transparency, participation, efficiency and effectiveness in the public sector [Huijboom, Van den Broek, 2011]. Open data policies have been established with the purpose to bring new economic opportunities through encouraging innovations, fostering digitalization, developing advanced products and services and providing further benefits for individuals, organizations and civil society as a whole. As discussed in the report of Carrara et al. (2015), the open data re-use can lead to many political and social benefits as well as to direct and indirect economic gains in the form of new revenues, value-adding activities, costs savings and jobs. Following the general Open data trend, different public, NGOs and private organizations and international bodies, deliver open cross-disciplinary datasets, available for further re-use, naming as for example: www.kaggle.com; google cloud platform (<https://cloud.google.com/public-datasets/>), open data network (<https://www.opendatanetwork.com/>) and many others.

However, the public statistics show that the free access to open data is not automatically leading to data use and re-use especially in business context [Welle Donker & van Loenen, 2017]. Even more, unanswered questions remain about the micro-economic and macro-economic effects from Open data re-use and further distribution of the Open Data economic gains [Davis&Perini, 2016]. Moreover, the development of new products and services out of public data and the emergence of new business models prove to be challenging tasks for all stakeholders, including business and public organizations, start-ups and non-for-profits. Even in the most advanced business case scenarios, it becomes clear that further efforts should be made to integrate open data into value-adding business models, business processes and services.

The emerging Industry 4.0 technology paradigm imposes new economy models based on "smart manufacturing" and "smart factories". Organized around big data, connected technologies such as complex cyber-physical systems, Internet of Things, 3D printing, cloud computing, artificial intelligence and robotics have the potential to disrupt value creation along different industries. Big data and advanced data analytics become the key ingredient of the new business models and business processes. However, Sommer (2015) warns, that new Industry 4.0 revolution can change the structure of the business landscape, leaving small companies incapable to survive the digital transformation, unable to adapt to the new-coming business realms. As a result, a question arises: Can

thus open data enhance the digital transformation of the SME companies?

The present research aims to outline the opportunities of companies and especially SMEs to integrate open data into their digital transformation process. By exploring the main elements of data-driven value creation process and data-based digital business models, a framework is proposed for value-adding activities of both open data providers and intermediaries within an open data ecosystem.

The paper is structured in four sections. The first section presents the main concepts of open data and the elements of the digital business models transformation within Industry 4.0 and smart factories. In the second section, the data-value driven models for value creation, the data-driven business models and open data value creation is explored. The next section outlines open data models and standards, further making assessment of Open data development in Bulgaria. Finally, the paper identifies and discusses the main difficulties and barriers for companies to implement open data analysis into their business models and there is proposed and discussed a new open data business model, fostering value creation within companies.

2. Open data, Industry 4.0 and company digital transformation

Open data is commonly defined as data, that can be freely used, re-used and redistributed by anyone – subject only at most, to the requirement to attribute and share-alike [Open Data Handbook, Open Knowledge International, 2015]. In order to be reusable, the open data should respond on two main conditions: to be legally open, or released under an open license, legally permitting its re-use and redistribution and to be technically open, or available in an open and machine-readable format, as a complete dataset and preferably for a free download (Open Data EU portal, <https://data.europa.eu/>).

The open data portals represent a critical data infrastructure as they connect data holders with data users, who in turn can re-use it into products and services that citizens and businesses can benefit from. The main European Open data hub is the European data portal (<https://www.europeandataportal.eu/>), launched in November 2014 with the aim to facilitate both data publishing and data re-use across different EU countries. The European data portal harvest the metadata of Public Sector Information (PSI) available on public data and geospatial portals across European countries and currently provide access to about 788,671 datasets. Furthermore, the

European data portal provides a wide number of services such as Open data e-learning and training, research publications, public surveys, Open Data barometers, policy recommendations and others. This way, European data portal becomes the main reference center for European open data initiatives. On European scale many other specialized open data portals, such as: INSPIRE (spatial data sets and spatial data services), Copernicus (land, marine, atmosphere, climate change, emergency management and security), GEOSS (Global Earth Observation System of Systems) have been launched. During the next years it is expected the European Open Science Cloud (EOSC initiative) to be launched. All these portals and initiatives come to show that further public datasets will be available for businesses, increasing their potential and capacity to monetize data resources into innovative products and services.

Industry 4.0 and smart factories designate a new trend toward existing industry digital transformation with extended smart and connected technologies. Almada-Lobo (2016) defines Industry 4.0 manufacturing transformation based on Cyber-Physical Systems (CPS) and Cyber Physical Production Systems (CPPS) toward mass customized, decentralized, vertically integrated, connected and mobile, cloud computing and advanced data analysis approach. Saldivar et al., (2015) further summarize that Industry 4.0 leads to a paradigm shift from centralized to decentralized manufacturing based on customer-triggered autonomous processes of cyber-physical systems. Recognizing the economic potential of Industry 4.0, a number of policy strategies have been implemented both on European and on national level [Digitizing European Industry EC portal].

Adoption of Big data or advanced data analysis will play a crucial role in the digital transformation process. As outlined in the whitepaper of Fraunhofer' Institute [Otto et al., 2016], data has changed its economic role in industry from "data as a process outcome" on "data as a process enabler" to become „data as product enabler" and finally transforming to "data as a product". This is confirmed as well by [Ylijoki & Porras, 2016], stressing on that big data will have disruptive effects on firms, ecosystems and businesses, leading to emergence of new business models and value-creation mechanisms. The accumulation and integration of big data, coming from different sources is seen as a must for developing adaptive, smart, customer-oriented business models and processes. Therefore further approaches have to be developed enabling companies to integrate both data from internal processes as ERP/CRM/SCM systems, IoT sources and private clouds with industry data, social media, open government data and open public data, scientific data, partner's/ suppliers/competitor's/ecosystem data and others. Thus, the role of big data and data analysis for companies changed substantially during the stages of digital transformation, leading to further impact on industries and economy as a whole.

Making an overview of the successful digital transformation processes of old and big companies, Sebastian et al., (2017) identified three main elements. The first one is the adoption of digital strategy and technology-inspired value proposition. The main digital strategies can be either customer engagement (adopting technologies for increasing loyalty and trust) or development of digitized solutions (integrating combination of new products, services and data). The second element is to develop an operational backbone and the third element is to create digital service platform, enabling rapid innovation and responsiveness to new market opportunities.

In conclusion, the digital transformation is a complex issue, consisting of different aspects such as adoption of new digital strategy (digital transformation vision), framework (operational backbone), ecosystem approach, adoption of open environment for experiments.

3. Data value chain, Business models, Data ecosystem

The main data value-driven models are based on business analytics or data analytics methodologies, aimed to analyze, predict and control processes in business and industry [Coleman, 2016]. The main three subcategories of business analytics are: descriptive analytics (summarize, condense and aggregate data from complex data sets, using graphics and aggregated statistical metrics); predictive analytics (enable forecasts of future effects based on historical data, comprising statistical learning, machine learning, data mining and knowledge discovery from databases), and prescriptive analytics (transforming the results of descriptive analytics and predictive analytics into business decisions, based on optimization theory and operations research and quantitative tools) [Coleman, 2016]. It should be pointed out as well that a substantial pre-condition for any data based models and analytics is the good data quality [Baesens et al., 2014]. For these reasons, the data-value chain should include careful procedures and oversights to ensure high data quality through all data steps: (1) initial collection, (2) storage and updating, (3) retrieval, and (4) processing and preparation for analysis.

Investigating both research and practitioners' literature on open data business models, Zeleti et al., (2016) identified 15 business models: Premium, Freemium, Open Source, Infrastructural Razor and Blades, Demand-Oriented Platform, Supply-Oriented Platform, Free as Branded, Advertising, White-Label Development Cost Avoidance, Sponsorship, Dual Licensing, Support and Services, Charging for Changes, Increasing Quality through Participation, and Supporting Primary Business. In summary, Zeleti et al., (2016) conclude that the main open data business models are Freemium, Premium, Cost Saving, Indirect Benefit and Parts of Tools. The main value proposition out of the open data can be Usefulness, Process Improvement, Performance and Customer Loyalty. Roman et al. (2017) analyze that databased business models depend on data suppliers, (from simple data supplier to service provider), data sources (whether the data is internal or external) and what is done with the data (ranging from providing data for reuse, analyzing and aggregating existing data or even providing services). The revenue model for the different strategies are mostly subscription based but can also entail "freemium", pay-per-use or advertising. The more complex business models are also harder to execute, prompting open collaboration and co-creation [Roman, Liu, Nyberg, 2017]. Further, the authors determine that when an individual or organization is comfortable with data commercialization models they start to release more data and try to move on to more complex business models. Toots et al., (2017) find out that open data-driven service creation should be a process of value co-production, invoking collaboration between different stakeholders such as public administration, citizens and businesses. The authors propose to use open data for the co-production of new public services, or services leading to new public value, and their framework relies on the use of agile development practices in the creation of data-driven services.

The European data portal (EDP) Report 1 (2016) defines the following data-value chain processes and the main types of business users as follows:

- Data creation/Enablers: organizations, facilitating the supply or use of Open Data;
- Data aggregation/Aggregators: organizations that collect and aggregate open and proprietary data;
- Data analysis/Developers: organizations that design, build and sell web-mobile-apps based on data analysis;
- Data-based products and services/Data enricher: organizations that use Open data to enhance their products and services.

In the report of EDP (2016) among EU countries the data enrichers are among the most popular open data re-users (49,73%), and most of them work to improve company performance. Data aggregators (29,29%) works in new digital business blocks, and developers (18, 26%) are focused in customer touch points and new digital businesses. In the report from 2017, the EDP specifies further business cases for open data use and reuse and identifies more specific business models among open data end users. All four types of business models exploit open data in different ways to create value, for themselves, for their clients or for society. Thus, according to the EDP report (2017), the main revenue sources for OD businesses are: selling services (42%), selling products and services (21%) and selling products (10%). Most of the organizations, exploiting open data as resource are start-ups, and most of them are active in the information and communication sector. In this report, businesses can specify their activity as 1) Enhancing products, 2) Enhancing services, 3) Process optimization, 4) Data as a service, 5) Information as a service, 6) Answers as a service, 7) Development of web or mobile applications; or several of these. Thus the most popular Open data use is for internal process optimization, on the second place come organizations who facilitate access to and services on (aggregated) open data for others, on third place are organizations who offer (data analytical) products and services based on Open Data and finally come organizations who do not add financial value but create societal value. The main revenue streams are mainly coming from subscription fees, advertising, licensing, and consulting fees, lead generations and analytics fees (EDP, 2017). Confirming that, the statistics from 2016 (EDP, 2016) shows that open data in EU contribute mainly to performance management (internal, cost-savings), new digital businesses, developing new customer touch-points, improve customer understanding, company process digitization, top-line growth, digitally modified business and others. Open data re-use mainly helps companies to understand better the customer experience: for example, adapting marketing campaigns by geographic regions, making specific customer segmentations according to demographics, improve customer self-services and digital touch points and others. As most public administrations in general generate data about the environment, the legal system and the public safety, yet most of the data re-users are interested in the following sectors: government & public sector, economy & finance, transport and more particularly business registries and company data. The organizations re-using the Open Data work mainly in the IT sector, the public sector, financial and insurance services, as well in health, education & research, transportation, energy & utilities, culture & tourism and real estates.

3.1. Open data ecosystem

Open data can be provided both from public authorities and government structures or by third-level providers (as for example open scientific data, industry-specific data and others). Therefore, open data ecosystem can include both public and private providers, end-users and intermediary organizations. Based on the Open Data Consumer's Checklist (Open Data Institute), a model of value-adding activities of both open data publisher and open data intermediary is proposed and presented on table 1.

Table 1: The role of the Data provider and Data intermediary for Open data value creation.

	Data Provider	Data Intermediary
Access	Provide access Ensure data availability	Data format/enrich data use by API/
Ownership and licenses	Guarantee data origin Anonymize private data Appropriate license	Appropriate licenses for data re-use
Form	Provide data in machine-reading form, Quality meta-data Initial data processing	Summary, aggregated form, syntactic and semantic transformations; compatibility with

		the other sets
Quality	Current and frequently updated datasets; Long-term commitment	Ensure data accuracy Enrich data context Handle/recover missing data
Support	Data set documentation Meta-data analysis Support Reporting for errors	Supporting end- user Ensure feed-back; Good dataset documentation

Open data ecosystem can include different stakeholders, such as business organizations, public organizations, start-ups, universities, open spaces, public innovation labs, living labs, third level partners and others. In the whitepaper of Fraunhofer institute, Otto et al, (2016) highlight the role of Industrial data spaces that combine both industry (private) data, club data, and open data and promote the development of public connector that will orchestrate the data flows. The role of the public connector represents a third-level provider who can become as well a boundary organization that supports university-industry partnerships, involve various stakeholders, students, NGOs and public society organizations, organizes and hosts various events such as hackathons and competitions. In order that an Open data ecosystem is sustainable, the main success factors are publisher' sustainability, governance, financing models, appropriate technical architecture and the use of metrics.

3.2. Open Data technical requirements and formats

The Open data technical requirements and standards aim to ensure its further re-use in machine-readable format. Open datasets can differ between: low frequency use datasets (<5%), mid frequency use datasets (5%-10%), high frequency use datasets (>10%). The high frequency domains are in line with the high priority domains identified by the European Commission: such as geospatial data, earth observation and environmental data, transport data, statistical data and selected company data. Some other technical data can be identified as well:

- Common open datasets structures: tabular, hierarchical and network data structures.
- Data types can vary, including specific examples of data types such as legislative, statistical and geographic data that can require special treatment.
- Common Open Data formats and standards are CSV, JSON, GeoJSON, KML, XML and RDF Turtle.
- The most popular machine-readable data formats are: CSV, XLM or XLS;
- Interoperability of Open Data portals and metadata is ensured by standards such as DCAT-AP.

3.3. Barriers for Open Data implementation

Among the main barriers, still hindering wider Open Data re-use as driver of Digital Transformation can be identified [Coleman, 2016, EDP, 2016]:

- Lack of awareness for OD initiatives;
- Lack of knowledge and skills to use OD;
- No clear governance and lack of responsible person within an organization, as a company data manager;
- Data quality: lack of capacity to combine open data with internal data;
- Lack of capacity for internal data management;
- Lack of appropriate data license.
- Big data architectures clearly represents an apparent barrier for SMEs, both from a financial and cultural point of view [Coleman, 2016].

4. Open data in Bulgaria

Bulgaria ranks among the EU trend setters for its Open data adoption, as identified in Open data maturity report (EDP, 2017). The open data portal in Bulgaria is launched in November 2014

following the Directive 2013/37/EU of the European Parliament and European Council, amending Directive 2003/98/EC on the re-use of public sector information text with EEA relevance. The adoption of the new amendments of the EU Directive induced the amendments in the Bulgarian Law for public information access, along with other changes in the legal framework. With decision of the Council of Ministers in 2015 is approved a list with 119 datasets, and additional 149 data sets have to be made publicly available till the end of 2017. Currently 6983 datasets are available on the Bulgarian OD portal <https://opendata.government.bg/> from 490 registered public data providers.

The Open data initiative in Bulgaria started in 2014 by a working group under the Council of Ministers' administration [Gerunov, 2015]. On Bulgarian OD portal, datasets are freely available for commercial and non-commercial use. The Open data project is developed on the open-source CKAN platform (<https://ckan.org/>), supported by Open Knowledge Foundation. Citizens and data-users have additional possibility to send feedback, to request public data, to specify public data that should be available in machine-readable data and other.

Among the main barriers for Open Data re-use in Bulgaria, the EDPa (2017) report identified two main issues: the lack of awareness and technical barriers, such as the low quality of data sets and low synchronization of information in the databases. Technical obstacles exist to automatically upload and update data with administrations that maintain and collect the information. Data users in Bulgaria still perceive the quality of Open Data to be low [EDPa, 2017]. The low quality refers to both the data itself as well as the accompanying metadata, and the lack of standardization users to develop permanent solutions to re-use Open Data in their processes.

Conclusions

The present research provides an overview of the main mechanisms for open data value creation. Among the main recommendations for companies are to start their digital transformation by developing open data projects, focused on performance management, developing customer touch points or starting new databased digital business. As the availability of open data will increase both in Bulgaria, in EU and internationally, defining now a company open data value strategy can become a trigger for further digital transformation. Open data strategies can help companies to improve customer experiences, to facilitate adoption of Cyber-physical systems and to enhance data-driven decisions, providing complex models for data re-use from different sectors and application areas.

Acknowledgement

The authors would like to acknowledge the support by the Interreg DIGITRANS: Digital transformation in the Danube region - <http://www.interreg-danube.eu/approved-projects/digitrans>.

References

Almada-Lobo, F. (2016). The Industry 4.0 revolution and the future of manufacturing execution systems (MES). *Journal of Innovation Management*, 3(4), 16-21.

Baesens, B., Bapna, R., Marsden, J. R., Vanthienen, J., & Zhao, J. L. (2014). Transformational issues of big data and analytics in networked business. *MIS quarterly*, 38(2), 629-631.

Carrara, W., Chan, W. S., Fische, S., & Steenbergen, E. V. (2015). Creating Value through Open Data: Study on the Impact of Re-use of Public Data Resources. European Commission.

Country Factsheet for Bulgaria, European Data Portal, https://www.europeandataportal.eu/sites/default/files/country-factsheet_bulgaria.pdf

Davies, T., & Perini, F. (2016). Researching the emerging impacts of open data: revisiting the ODDC conceptual framework. *The Journal of Community Informatics*, 12(2).

Dawes, S. S., Vidasova, L., & Parkhimovich, O. (2016). Planning and designing open government data programs: An ecosystem approach. *Government Information Quarterly*, 33(1), 15-27.

Digitizing European Industry EC portal, <https://ec.europa.eu/digital-single-market/en/policies/digitising-european-industry>

EDP, 2016, Analytical Report 1: Digital Transformation and Open Data, available on <https://www.europeandataportal.eu>

EDP, 2016, Open Data Goldbook for Data Holders and Data Managers, available on <https://www.europeandataportal.eu/sites/default/files/goldbook.pdf>

EDP, 2017, Open Data Maturity in Europe, available on <https://www.capgemini.com/wp-content/uploads/2017/11/report-open-data-maturity-in-europe-2017.pdf>

EDPa, 2017, Analytical Report 5: Open Data Barriers, available on <https://www.europeandataportal.eu>

European Commission. 2011. "Open Data: An Engine for Innovation, Growth and Transparent Governance." Brussels. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0882:FIN:EN:PDF>.

Gerunov, A., 2015, Open Data: Policy and Implementation in Bulgaria. *Big Data, Knowledge and Control Systems Engineering*, 1-11.

Huijboom, N., & Van den Broek, T. (2011). Open data: an international comparison of strategies. *European journal of ePractice*, 12(1), 4-16.

Open Data Handbook, Open Knowledge International, 2015, <http://opendatahandbook.org/en/what-is-open-data/index.html>

Open Data Institute, Open Data Consumer Checklist, <https://theodi.org/guides/the-open-data-consumers-checklist>

Otto, B., Juerjens, J., Schon J., Auer S., Menz N., Wenzel S., Cirullis J., (2016), Industrial Data Spaces, Fraunhofer Institute whitepaper available on: <https://www.fraunhofer.de/content/dam/zv/en/fields-of-research/industrial-data-space/whitepaper-industrial-data-space-eng.pdf>

Roman, M., Liu, J., & Nyberg, T. UNIVERSITY-INDUSTRY COLLABORATION THROUGH BIG DATA AND OPEN SCIENCE. ICEIRD conference proceedings, 31 Aug–1 Sept 2017, 371.

Saldivar, A. A. F., Li, Y., Chen, W. N., Zhan, Z. H., Zhang, J., & Chen, L. Y. (2015, September). Industry 4.0 with cyber-physical integration: A design and manufacture perspective. In *Automation and computing (icac)*, 2015 21st international conference on (pp. 1-6). IEEE.

Sebastian, I. M., Ross, J. W., Beath, C., Mocker, M., Moloney, K. G., & Fonstad, N. O. (2017). How Big Old Companies Navigate Digital Transformation. *MIS Quarterly Executive*.

Sommer, L. (2015). Industrial revolution-industry 4.0: Are German manufacturing SMEs the first victims of this revolution? *Journal of Industrial Engineering and Management*, 8(5), 1512.

Toots, M., McBride, K., Kalvet, T., Krimmer, R., Tambouris, E., Panopoulou, E., ... & Tarabanis, K. (2017, September). A Framework for Data-Driven Public Service Co-Production. In *International Conference on Electronic Government* (pp. 264-275). Springer, Cham.

Welle Donker, F., & van Loenen, B. (2017). How to assess the success of the open data ecosystem? *International Journal of Digital Earth*, 10(3), 284-306.

Ylijoki, O., & Porras, J. (2016). Perspectives to definition of big data: a mapping study and discussion. *Journal of Innovation Management*, 4(1), 69-91.

Zeleti, F. A., Ojo, A., & Curry, E. (2016). Exploring the economic value of open government data. *Government Information Quarterly*, 33(3), 535-551.

INDUSTRY 4.0 and TURKISH NATIONAL INNOVATION SYSTEM: CHALLENGES and PROSPECTS

Erkan Erdil¹ and Şeyda Ertekin^{2,3}

¹Department of Economics, Middle East Technical University, and Research Center for Science Technology and Policies (METU-TEKPOL), Üniversiteler Mahallesi, Dumlupınar Bulvarı No:1, 06800, Cankaya-Ankara/ Turkey. erdil@metu.edu.tr

²Department of Computer Engineering, Middle East Technical University, and METU-BİLTİR Research Center Digital Transformation & Industry 4.0 Platform, Üniversiteler Mahallesi, Dumlupınar Bulvarı No:1, 06800, Cankaya-Ankara/ Turkey. sertekin@metu.edu.tr

³MIT Sloan School of Management, Massachusetts Institute of Technology, 30 Memorial Drive, Cambridge MA 02142 USA. seyda@mit.edu

Abstract: This study discusses the structure of Turkish National Innovation System (NIS) and challenges faced in the last decade in the context of the digital transformation. As a developing country and a member of G-20, how these challenges of Turkish NIS are mitigated and further be dealt with. It comprises lessons and provides cases for various similar NISs. In order to evaluate and provide policy recommendations for accelerating the transformation of Turkish economy, it benefits from systems approach as a basic academic framework. It is found that Turkey faces four key structural challenges calling for urgent response for their targets of 2023 (hundredth year of the Republic), namely productivity, growth, employment and investment. Implementing a relatively simple rule compatible with the peculiarities of the system and focusing on the diversity of policy mix, the study proposes ways to mitigate these structural challenges towards digital transformation.

Keywords: INDUSTRY 4.0, DIGITAL TRANSFORMATION, NATIONAL INNOVATION SYSTEMS, STI POLICY, STRUCTURAL CHALLENGES, TURKEY

1. Introduction

The unavoidable introduction of technological changes in the life of modern *homo sapiens* not only alters the humanity itself yet transforms societies and socio-economic structure in a drastic manner. The recent discussions on the so-called industry 4.0 or digital transformation seems to have such a capacity. It is main peculiarity is on the production, consumption and marketing of the goods and services. However, what is deep inside is the restructuring of human-human and human-machine interactions in a wider context. In this paper, we aim to provide a brief examination on policy impacts of the possible reorganization in the context of an emerging economy.

In fact, digital transformation strategy should be rooted at micro level firm strategy. However, the governments must consider the wider impacts at meso and even at macro levels. The policies and specific public strategies have to enhance the applicability of micro strategies especially in emerging countries like Turkey. As noted by OECD (2005) with a special appendix, one of the major shortcomings of developing countries in terms of innovative activities is the existence of problems in the *innovation landscape* especially weak innovation systems as compared to developed world. Another connected issue is the capacity and capability of qualified personnel needed for the digital transformation. As evident from the data¹, the emerging economies have also problems with the education systems. These problems necessitate strategic public intervention for the realization of digital transformation; otherwise the results for some of the developing countries may be detrimental and traumatic.

2. Turkish NIS in Perspective

The last decade has witnessed a shift from horizontal focus to sectoral focus in Turkish R&D and innovation policies. Moreover, following the adoption of the National Science, Technology, and Innovation Strategy 2011-2016 by the Supreme Council for Science and Technology (SCST), there has been a paradigm shift towards a target and mission-oriented approach. In fact, the implementation of such an approach has close links and likelihood to feed up digital transformation in the next decades. The detailed structure of STI system with their systemic functions is given in Figure 1.

The National Science, Technology and Innovation Strategy (2011-2016) document, called as NSTIS (UBTYS) 2011-2016, is still valid as the most important element of the national R&I

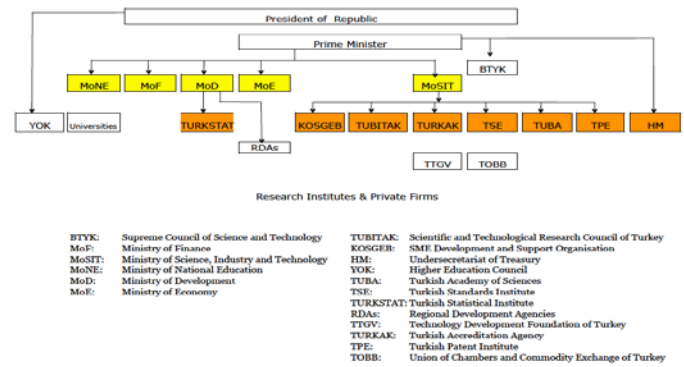


Figure 1: Turkish NIS

Strategy as presented by Figure 2. UBTYS 2011-2016 is preceded by Vision 2023 though some changes were amended. The vision of the strategy is defined as "*to contribute to new knowledge and develop innovative technologies to improve the quality of life by transforming the former into products, processes, and services for the benefit of the country and humanity.*"

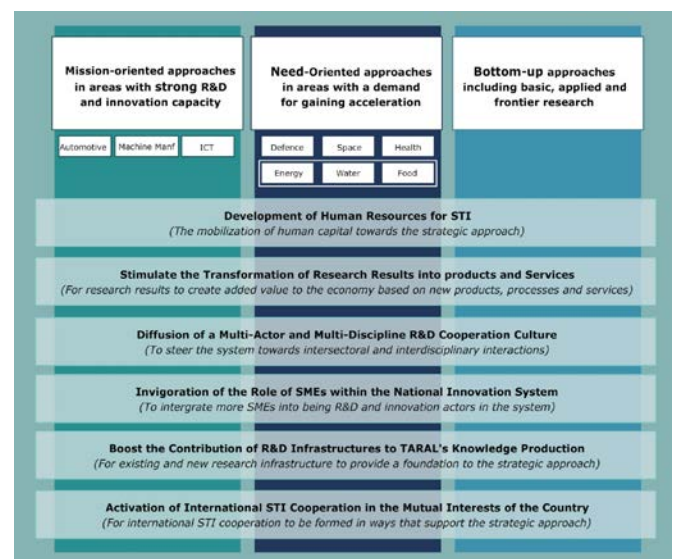


Figure 2: Strategic Framework of UBTYS 2011-2016

¹ See <http://datatopics.worldbank.org/education/> for an extensive dataset.

3. An Empirical and Policy-Oriented Snapshot on Digital Transformation

This section will focus on the possible repercussions of digital transformation at various levels, namely micro, meso and macro levels, in a policy context. METU-Digital Transformation/Industry 4.0 Platform notes that²

The world has recently witnessed the new concept of “Digital Transformation” which is also known as “4th Industrial Revolution” and “Industry 4.0”. Digital Transformation aims to support human capabilities through cyber-physical systems, smart factories, communication among machines and humans, and data-driven decision support systems. Digital transformation requires human capital development by providing collaborative learning networks to build multi-disciplinary communities of practice.

The new product lifecycles are not only related with the personalized customer demand and extends the existing issues of product development, order, production and distribution of a product to final customer but also its recycling as well with the connected services. However, such a systematic relation will, indeed, needs the establishment of real-time availability of all information concerning each phase of manufacturing, marketing and even recycling. This means the dynamic accessibility to the data that necessitates interconnection data-generating agents such as persons, firms, items, and various systems. Therefore, such an interconnection ends up with a value-creating networks that generates a dynamic optimization in terms of use of resources, cost, and accessibility.

First of all, the transformation aims to provide the digitization and integration of vertical and horizontal supply and value chains. In the context of emerging economies not only value but also supply chains are still relevant for the policy concerns since most of these countries has not already enjoyed the full advantage of the so-called ICT Revolution. The transformation vertically digitizes and interconnects the nodes inside the organization in all phases of manufacturing, sales, service and distribution. All data are collected from and distributed to nodes throughout the organization at a real-time basis. Connections are realized through cyber physical systems. Artificial intelligence and augmented reality applications are employed where needed. Outside the organization, horizontal integration takes place to efficiently reach to suppliers, customers and all agents of the value chain. The same data processing methods are used in horizontal integration as in the case of vertical integration. In these processes, smart products have information about their assembling phases. The model uses various digital technologies as depicted in Figure 3. The employed digital model and data-generating processes are used to service suppliers, customers and all agents in the value chain. In either type of integration, human is considered as the key determinant of creating value added. Combined with the well-designed business models run by humans, the system is expected to produce efficient results. Therefore, it brings a new interaction of digital model with the business model which complements each other instead of being a basic substitute of humans with machines.

In fact, the system will bring about efficiency both in input side and output side. However, it will be misleading to treat the system functioning in such a linear manner. The social behavior which is not totally predictable with the existing data is still on the scene. Thus, the system will not able to consider non-linearities with a stochastic modelling yet it optimizes the activities though not always ends up with the first-best solutions. The digital transformation is claimed to ensure the efficiency of invested capital, labor, materials, energy and time by 30-50% while

decreasing the consumption of other resources by 20-25% (McKinsey, 2015).

Industry 4.0 framework and contributing digital technologies

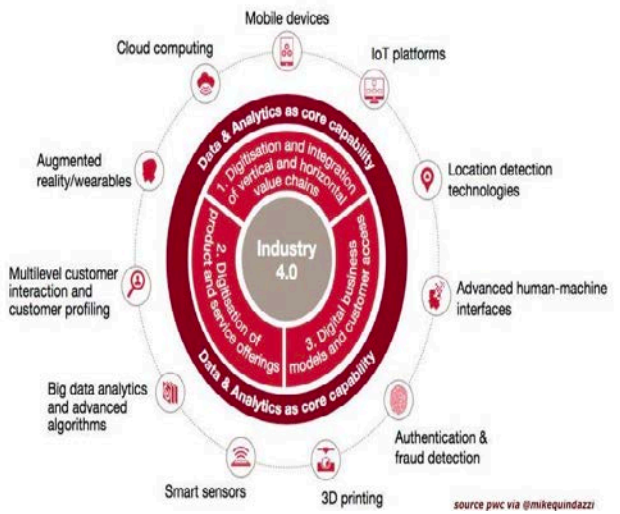


Figure 3: Contributing Digital Technologies to Digital Transformation³

In turn, increasing the efficiency and competitiveness of organizations both in the private and public sector. The most important value added is in the domain of user-focused approach utilized throughout the system such as customized innovative products, decreasing the impact of time constraints on orders, etc. However, to enjoy the full benefits of the system both in the production and consumption side, the product and service providing organizations should have a strategic approach to employ the digital transformation starting with a road map, then to strategy. It also necessitates a sustainable monitoring approach that can be applied rather easily with the existence of the big data and its applications to process this data. The ultimate mega aim is to construct a digital ecosystem on a global scene with a mission of increasing the wealth of humanity.

4. Linking Turkish NIS and the Digital Transformation

At the 29th meeting of BYTK in February 2016, three significant decisions are taken towards transition of Turkish industry for increasing international competitiveness in technology production:

- Developing an implementation and monitoring model for smart manufacturing in coordination with all stakeholders
- Increasing goal-oriented R&D efforts in critical and pioneering technology areas (cyber-physical systems, AI/sensor/robotics, IoT, big data, cyber security, cloud techs, etc.)
- Designing support mechanisms for manufacturing infrastructures to develop critical and pioneering technologies.

In accordance with these decisions, TÜBİTAK first carried out a survey with the stakeholders, then a prioritization study was carried out through an expert workshop, followed by a focused group meeting. According to results of the survey on 1,000 firms, only 22% reported that they have a detailed knowledge on smart manufacturing systems (TÜBİTAK, 2017). The highest awareness is observed in electronics, software and materials sectors. Among the surveyed firms, 50% have a strategy to integrate smart

³ Thanks to [Tamara McCleary](#) @TamaraMcCleary

² http://www.biltir.metu.edu.tr/Flyer_draft_2017_English.pdf

manufacturing systems in their production processes (TÜBİTAK, 2017). Regarding the level of digital maturity, the Turkish industry is between the 2nd and 3rd industrial revolution and the most mature sectors are the materials sector (rubbers & plastics), computers, electronics and optical devices as well as the automotive and white goods sector. Three technologies that will provide the most added value according to Turkish firms, are automation & control systems, advanced robotic systems as well as additive manufacturing. The expectation is that these technologies will find their ways mostly in the machinery & equipment sector, the computers, electronics and optical devices sector as well as the automotive and white goods sector. In the prioritization phase, 3 technology groups, 8 critical technologies, 10 strategic targets and 29 products were determined. The technology groups, strategic targets and underlying technologies are as follows:

1. Digitalization, with a focus on big data & cloud computing, virtualization and cyber security. The following targets are being defined:
 - Secure, private cloud service platform: develop secure, private, intelligent and scalable cloud service platforms for end devices, algorithms and applications.
 - Big data analytics: collect, process, correlate, analyse, report and use in decision support systems. Cyber security solutions: develop cyber security solutions Industry 4.0 applications.
 - Modelling and simulation: development of modelling and simulation technologies
2. Connectivity, with a focus on the Internet of Things (IoT) and sensor technologies. The following targets are being defined:
 - Industrial IoT platform: Establishment of digital platform of industrial IoT with interoperability, increased security and reliability, and development of software and hardware for industrial endpoint equipment.
 - M2X software and equipment: development of data storage technologies suitable for data emerging with reliable and innovative M2X (Machine-Machine, Human-Machine, Machine-Infrastructure) software and / or hardware that will increase the quality and productivity during the product life cycle.
 - Innovative sensors: development of industrial, physical, chemical, biological, optical, micro-nano sensors; intelligent actors; industrial, wireless, digital sensor networks; artificial vision, image processing, innovative sensor applications and heavy conditions resistant sensors.
3. Future factories, with a focus on additive manufacturing, advanced robotic systems and automation & control systems.
 - Robotic, automation, equipment, software and management systems: developing intelligent production robots, equipment and software / management systems that can compete in the international markets in terms of technology and cost, also accessible by SMEs.
 - Supplementary manufacturing materials, equipment and software: development of raw materials, production equipment and necessary

software and automation systems used in additive manufacturing.

- Intelligent factory systems: development of intelligent factory systems and components and middleware software technologies.

TÜBİTAK's national call for research proposals topics for 2016 and 2017 already reflect a focus on advanced manufacturing technologies as well as the Internet of Things. Specific focus is on:

- Additive Manufacturing:
 - Multilayer additive manufacturing
 - Rapid prototyping and 3D printing technologies
 - CAD/CAM, simulation & modelling software
 - Robotics and mechatronics
 - Flexible manufacturing
- Internet of Things
 - Sensors and sensing systems
 - Virtualization
 - M2M communication
 - Cloud computing

According to TÜSİAD (2016), the expected impacts of the digital transformation on Turkish economy are as follows:

- **Productivity gains of 4 to 7 percent** on an annual basis.
- Despite the predicted low skilled job loss, **5 percent absolute increase in employment** is expected.
- **Higher-skilled labor force** structure is expected to prepare a **stronger know-how base** for Turkey.

Additional total manufacturing based growth of up to 3 percent per year, meaning **1 percent growth effect on Turkish GDP**. Turkish producers are required to **invest about 3 to 5 billion Euro per year** over the next ten years.

According to TÜSİAD (2016) study as depicted by Figure 3, four sectors have a considerable strength in digital transformation, namely automotive, machinery, white appliances and chemicals. It can be treated as a first attempt to measure readiness of Turkish industry for the digital transformation. Turkey has various strengths towards this transformation. First of all, Turkey has a long tradition of manufacturing expertise and exhibits a significant progress with the development of key industries and growing trade and investment. Second, the last decade has witnessed a rapid export growth which in turn accelerates the articulation of Turkish industry with the global counterparts. The well-developed and relatively large domestic market provides opportunities to process market information and feedback for the production. Finally, rising public incentives targeting to increase private sector RDI, export share of hi-tech sectors, to strengthen research commercialization and entrepreneurship. In the next section, we will discuss the major structural challenges of Turkish NIS with respect to the digital transformation.

Industry 4.0 lever	Company	Examples
1 Integrated, automated and optimized production flow	White appliances	Integrated quality management Tracks products within the manufacturing process and correlates failure data from testing after front-end-production to reduce waste and improve processing
	Machinery	Integrated design data Utilizes vertical data integration from design to the end-of-line of its semi-automated manufacturing process for optimization of operations
	White appliances	Horizontal data integration Enabled its suppliers to view selected ERP data to tie them closer to an integrated production process in its factory Cerkizkoy
2 Virtual product design	Automotive	Virtual factory and product design Offers a joint solution to integrate factory and product design to optimize manufacturing through factory simulation based on the actual manufacturing needs
3 Flexible manufacturing	White appliances	Flexible manufacturing robots Implemented a manufacturing line which communicates with RFID-based smart products and adjusts tools and manufacturing tasks to product type
4 Automated logistics	Automotive	Laser-guided automated guided vehicle (AGV) Operates a laser-guided AGV logistics system, where the host computer controls inventory and schedules, controls deliveries and routes the AGVs
5 Learning and self-optimizing	Chemicals	Self-optimizing process flow Works on an IT algorithm to optimize the quality of the end products process through recognition of disturbances in the basic materials mix

Figure 3: The Levers and Sectors for the Digital Transformation in Turkish Industry

5. Structural Challenges of the National R&I System

According to the European Innovation Scoreboard 2017 Turkey is a **Moderate Innovator**⁴. Innovation performance has been improving at a slow but steady rate between 2008 and 2014, and for 2015 and 2016 a sharp increase can be observed. Turkey is catching up to the EU; its relative performance has improved from 38% in 2008 to 39% in 2014 and then jumped to 51% in 2015 and approximately 60% in 2016 turning the country from a Modest into a Moderate Innovator. Therefore, its performance relative to the EU has increased strongly. However, it suffers some challenges as presented in Table 1.

Table 1: Structural Challenges of National R&I System

Challenge	Main Conclusion
Promoting research commercialisation from universities	The enrichment of the policy mix with a variety of measures (financial, non-financial, etc.) will help to address this challenge
Increasing the number of innovative high-growth start-ups	The underdeveloped venture capital and business angels markets, as well as the limited number and variety of policy measures for start-up creation, are crucial barriers.
Increasing R&D and innovation capabilities of the private sector	The low levels of absorptive capacity of the business sector, particularly which of MSMEs, is a barrier to increase R&D and innovation performance.
Focusing on strategic approach on access to finance	The impact of existing strategies should be evaluated and the policy mix should evolve based upon these evaluations.
Increasing availability and quality of research personnel	Further efforts and diversified measures are needed to develop human resources in a way that the absorptive capacity of companies is enhanced, and the quantity and quality of researchers are increased.

⁴ European Innovation Scoreboard 2017
https://www.rvo.nl/sites/default/files/2017/06/European_Innovation_Scoreboard_2017.pdf

6. Concluding Remarks

In Turkey, there exist various instruments to tackle structural challenges towards the digital transformation summarized in Table 1. The most significant shortcoming of all these measures being the inexistence of evaluation studies on these support programmes. Although the establishment of evaluation office at MoSIT is a step forward, another concern is an urgent need to develop an evaluation culture and establish an effective mechanism for systematic evaluation of the public R&D funding system, policies and policy measures on the basis of internationally recognised criteria. Therefore, without an attempt of systematic impact assessment and evaluation studies, it is not possible to evaluate the consequences of the current funding system. Turkey is a support schemes' heaven in some sense yet it has not been evaluated whether these schemes result in optimal outcomes or if sub-optimal ones are obtained. Therefore, how to deal with the difficulties are not clear. For instance, although various interfaces like technology parks, incubators, TTO's etc. were created to speed up the innovative activities of firms and to enhance university-industry interactions, there is no real strategy pertaining to knowledge transfer among university and industry. There is an urgent need to create favourable conditions to foster a growing and robust venture capital market, especially for early stage investments. Moreover, the rules and procedures and streamline processes for starting up, running and terminating a business should be improved for the effectiveness of entrepreneurship incentives. The rules for starting up and running a business are not simple nor designed from an SME perspective. Heavy bureaucracy in applications and red tape are still observed. Although the legal framework seems to be transparent and up-to-date, clientelism is a fact at some instances (Luca, 2016 and Ocakli, 2016). Another measure to be introduced is the development of efficient standard-setting system supporting innovative products and services.

In sum, Turkey is a heaven for policy documents, strategies and mechanisms yet it suffers a lot in terms of implementation. Besides the structural challenges mentioned above, there is a need for higher skilled labor force but the frequent changes in national education system seems to be a barrier for such an attempt. Another risk the premature deindustrialization especially connected with SMEs. The low export share of hi-tech products and also seem to be a barrier for an accelerating transformation. All these structural challenges can be mitigated with a holistic approach with the contribution of all stakeholders in the ecosystem including public sector, large corporations and SMEs and knowledge generators. All the stakeholders in the ecosystem need to prepare road maps in accordance with their business models for the digital transformation by explicitly specifying the required policy tools at different levels, namely micro, meso and macro levels. These business models should consider the resolutions for the problems involved in horizontal and vertical supply and value chains. On the other hand, public sector should outline an action plan especially for the infrastructural problems such as skill requirements, ICT infrastructure, SMEs capabilities, etc. Otherwise, the digital transformation process becomes a threat on the road towards the deindustrialization of the country rather than being an opportunity.

References

- Luca, D., 2016, Boon or bane for development? Turkey's central state bureaucracy and the effective management of public investment, *Environment and Planning C: Politics and Space*, 35, 939-57.
- McKinsey, 2015. Industry 4.0 How to Navigate Digitization of the Manufacturing Sector.
- Ocakli, F., 2016, Political entrepreneurs, clientelism, and civil society: supply-side politics in Turkey, *Democratization*, 23, 723-746.
- PWC, 2016. Industry 4.0: Building the Digital Enterprise.
- TÜBİTAK, 2017. Yeni Sanayi Devrimi Akıllı Üretim Sistemleri Teknoloji Yol Haritası, Ankara: TÜBİTAK.
- TÜSİAD, 2016. Türkiye'nin Küresel Rekabetçiliği için bir Gerekliklik olarak Snayi 4.0, Gelişmekte olan Ekonomi Perspektifi, İstanbul: TÜSİAD.