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Economic cycles and recent world crises on the example of Ukraine

Galyna Zhavoronkova, Vladimir Zhavoronkov, Irina Panasiuk,
National Aviation University,
Kyiv, Ukraine
zhavor@ukr.net

Annotation. The theory of cycles as an objective form of development of the world economy (national economy) is studied. The phases of the economic cycle are named: recovery, prosperity, recession, depression. It is recognized that today the whole world is isolated due to the COVID-19 virus infection and all countries are experiencing an economic crisis. In these circumstances, it is important to explore ways out of this crisis and prevent the collapse of the economic system as a whole. The purpose of this article is to determine the theoretical and institutional causes of economic cycles to predict the crises that arise, and to find ways to mitigate their negative consequences. The theory of economic cycles and stages of their passage is generalized; conducted an analysis of Ukraine's economy before and during the crisis of 2019-2020. The application of the historical method allowed to use experience, generalize and systematize the development of economic theory and use the collected and systematized data to identify cause-and-effect relationships and predict the future dynamics of Ukraine's economy.

KEYWORDS: ECONOMIC CYCLE, CRISIS, INSTITUTIONAL APPROACH, COVID PANDEMIC.

1. Introduction

The last global crisis was the 2008-09 financial crisis, which began in the United States in 2007. It quickly escalated into a global crisis that led to bank failures, falling stock indexes, and a sharp drop in the value of stocks and commodities around the world. The world has entered a global recession that is causing widespread business cuts, rising unemployment and declining government revenues [14]. Rescue packages for the economic and financial sectors have been announced in almost all industrialized countries and many emerging countries. The crisis has revealed fundamental weaknesses in financial systems around the world; showed how interconnected and interdependent economies are today. Today, when the whole world is isolated due to the COVID-19 virus infection, all countries are experiencing a recession and crisis [9]. Therefore, in these conditions, it is important to explore ways out of this crisis and prevent the collapse of the economic system as a whole.

2. Stages of research of economic cycles

A characteristic feature of cyclicity is the spiral movement of the economy, which indicates a tendency to progressive development. Today's cyclicity is one of the ways of self-regulation of the market economy.

Theories that explain economic cycles by external causes (wars and various political misunderstandings, the development of new territories) are called external. For short cycles, the material basis is the processes that have a place in the sphere of monetary relations. They are characterized by sharpness and intensity.

The average cycles are differentiated by the term of return to the pre-crisis state and by the depth of the fall of the economy. Today there are several dozen views on the emergence of the preconditions of the average economic cycles, among them are some:

- 1) discrepancy between the available money capital and its offer as the reason of occurrence of cycles;
- 2) the cycle as a result of technical innovations, which requires an increase in investment;
- 3) the main reason for the decline - the contradiction between the common nature of production and the private form of attracting its results;
- 4) cyclicity is caused by excess savings and lack of investment in production [13].

Despite the differences in the above approaches, all the mentioned concepts understand the economic cycle as a product of internal causes.

Kondratiev theory (so-called long waves) had a significant impact on the further development of this area of research [4]. According to this theory, scientific and technical progress develops with a cycle of 50-60 years. The material basis of these waves is the

technological renewal of capital goods and the increase of the professional level of workers. In the structure of long-term cycles, Kondratiev identified two phases of development: ascending and descending [2].

Studies of the origin of the cyclical nature of social reproduction in the context of state regulation of the economy have contributed to the spread of new ideas on this issue. Among these ideas are the concepts of "equilibrium business cycle" and "political business cycle" [7]. The concept of "equilibrium business cycle" implies the ideas of monetarism: the state acts as a generator of monetary "shocks" that bring the economy out of equilibrium and maintains the cyclical nature of social reproduction. Proponents of the theory of rational expectations believe that individuals and legal entities are able to assess the motives of decisions of civil servants and respond in a timely manner to their decisions.

The concept of the "political business cycle" is based on the fact that the dependence of inflation and unemployment is determined by the Phillips curve: the feedback between these values: lower unemployment means faster price increases.

3. The length of economic cycles on the example of the economy of Ukraine

In the ranking of countries by GDP, Ukraine ranks 57th. The real GDP of Ukraine as of 01/01/2017 amounted to UAH 984.016 million (Fig. 1).

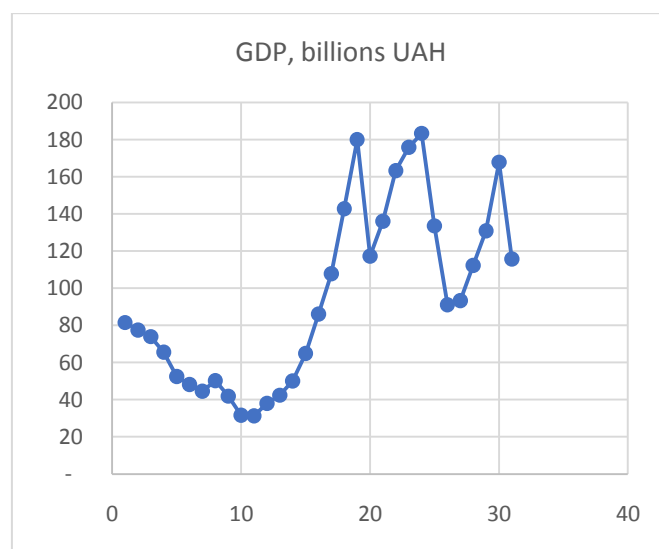


Figure 1. GDP of Ukraine from 1990 to 2020 [6].

This year, Ukraine's economy has shown growth in this indicator (2.3%) for the first time since 2013. The fall in GDP began in 2013 and amounted to 0.027%, accelerating in 2014-2015 due to the political, economic crisis, military action. During these years, the total decline was about 16% [6]. The decline in GDP was caused by deterioration in almost all sectors of Ukraine's economy. Destruction of production facilities and transport infrastructure.

As you can see from Fig. 2, since 2015 the inflation index has been falling. Today, inflation is 2.7%, which is a good sign of economic growth. The growth of the indicator is observed only from 2016 to 2017.

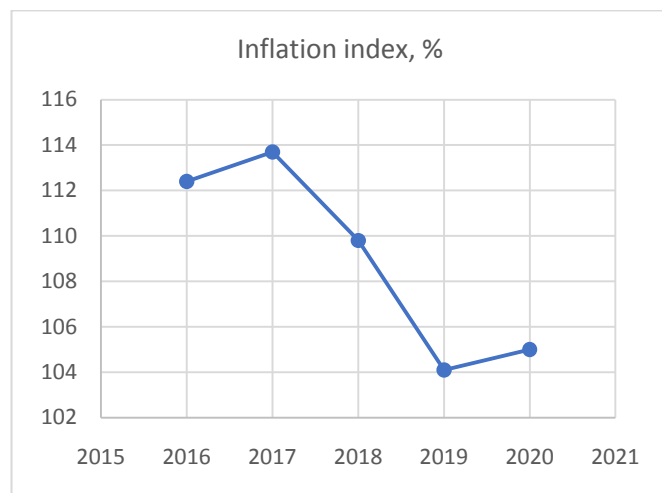


Figure 2. Dynamics of economic indicators of Ukraine from 2015 to 2020 [6]

As we see from Fig. 3, from 2015 to 2016 the figure fell, from 2016 to 2017 it increased, from 2017 to 2018 it fell again, from 2018 to the present it is growing.



Figure 3. Dynamics of gross external debt of Ukraine from 2015-20 [6]

Economic crises in Ukraine were permanent in 1997, 2007 and 2013. Thus, from 1990 to 1996 the economy experienced a phase of crisis, from 1996 to 1998 a rise, from 1998 to 2001 a decline, from 2002 to 2008 a rise again, as the economy successfully emerged from the decline of 1998-2001, and from 2008 to 2010 the recession caused by the global financial crisis, from 2010 to 2013 the rise again, and from 2013 to 2016 the crisis

sharply caused by actions in eastern Ukraine, from 2016 to the present day the rise and gradual stabilization of the economy (Fig. 4).

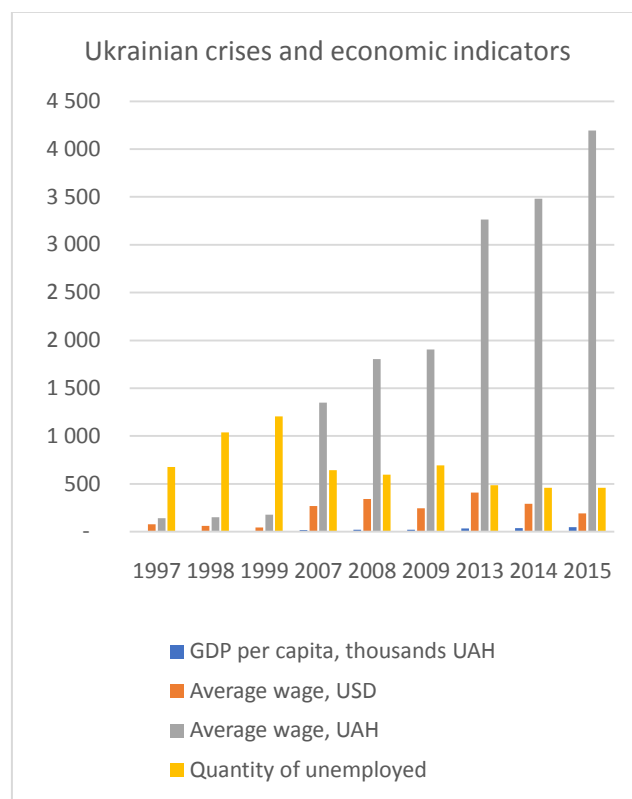


Figure 4. Crises of Ukraine and economic indicators [6]

That is, since 1990, Ukraine has experienced three crises (for 20 years). On average, the crisis occurs every 5-7 years.

4. Ukraine's economy during the crisis from the coronavirus pandemic

Ukraine's economy has been hit hard by the COVID-19 outbreak. GDP decreased by 11.4% in the second quarter of 2020 [2]. However, the negative impact was less severe than originally anticipated, as the full-scale blockade lasted only from mid-March to early May and was replaced by adaptive quarantine, which allowed many services (except passenger transport) to return to normal operation. The next block took place in January 2021.

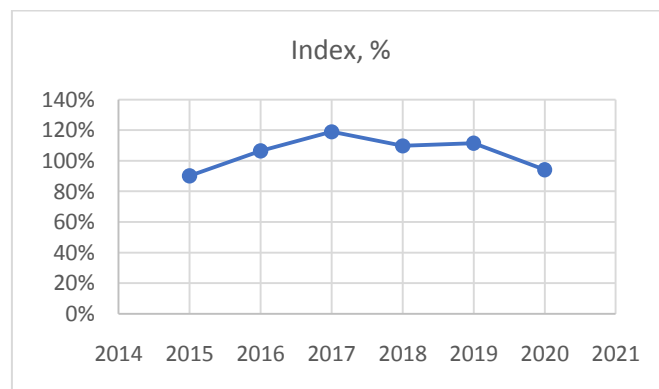


Figure 5. Dynamics of the index of real wages of Ukraine in 2014-2020 [6]

The real wage index (Fig. 5) grew from 2018 to 2019, and in 2020 domestic demand was supported by the recovery of real

wages (growth of 4.8% year on year in June compared to -0.4% in April) and constant receipt of remittances (Fig. 6). Metals and mining, as well as the manufacturing industry, are significantly affected by weak external demand.



Figure 6. Money transfers to Ukraine from abroad from 2008 to 2020 [6]

Improvements in conditions and a contraction in imports contributed to the current account surplus of 4.8% of GDP in January-July. Remittances were relatively resilient (Figure 6), declining by 10% in the first half of the year, while private capital inflows also resumed after a short period of limited outflows in the second quarter. This helped reduce external financing needs and restore international reserves, which stood at \$ 28.5 billion at the end of July. USA (Fig. 7, 8), which was about 4.6 months of imports the following year.



Figure 7. Official international reserves of Ukraine, mln USD [6]

Starting in 2019, tight monetary policy, as well as control over public sector wages and current expenditures, have helped reduce inflation from more than 9% in 2018 to 2.4% in July 2020. This was below the Central Bank's 5% inflation rate, allowing it to lower its key policy rate by more than 10 percentage points to 6% in June 2020. Expecting inflation to average 6.7% in August, real interest rates are close to zero, and further easing may contribute to inflationary pressures in light of more tailored fiscal policies.

Demand for credit declined in the second quarter, reflecting the impact of the COVID-19 shock. Bank liquidity remains

supported by a significant increase in deposits (Fig. 9). At the level of 25% (level 2), capital reserves significantly exceed the regulatory minimums, while the ratios of outstanding loans in the second quarter of the year were 96.8%.

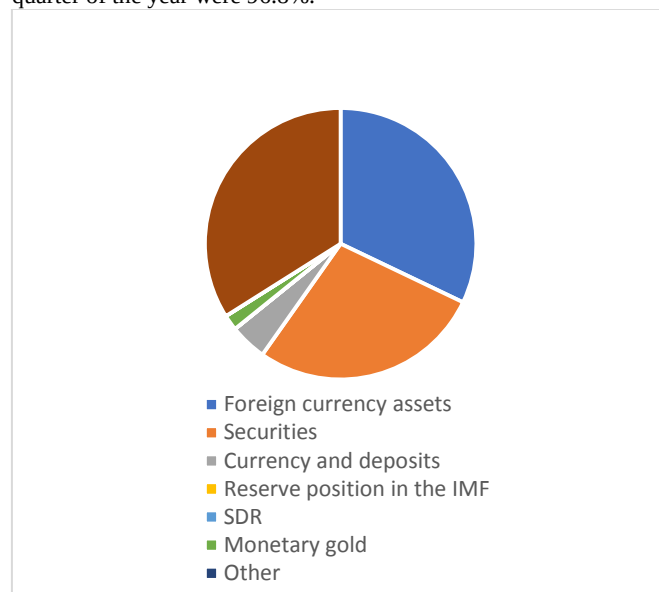


Figure 8. Official international reserves of Ukraine as at 31/12/2020, mln USD [6]

Fiscal pressures in 2020 stemmed from declining revenues, additional costs associated with COVID-19 support measures, and large debt payments. As a result, an additional budget was adopted in April, which provided for a budget deficit of 7.6% of GDP (compared to 2.5% in the initial budget). Significant financing needs during 2020 were mitigated by official funding from the European Union and the International Monetary Fund of \$ 2.7 billion, plus the issuance of 12-year Eurobonds worth \$ 1.3 billion in July. Domestic financing remains sufficient to cover domestic debt repayment needs. Ukraine still expects to attract additional official funding (from the IMF, the World Bank and the EU) of \$ 2.9 billion by the end of the year. If these funds are withheld, the government will have to restrain spending or borrow more in its own country.



Figure 9. Total assets of Ukrainian commercial banks as at 01/12/2020, mln UAH [6]

Moderate poverty (the World Bank's national methodology for Ukraine) fell from a peak of 26.9% during the 2015 crisis to about 17.8% in 2019 due to a decrease in the unemployment rate to 8.6% and an increase in real wages by 9.8 % (Fig. 10). Disposable income increased by 6.6% in the first quarter of 2020, but the COVID-19 outbreak is likely to have a negative impact on employment and real wages and create conditions for increasing poverty.

Poverty, based on the international level of 5.5 US dollars per day, the poverty line in Ukraine is low, and it is expected to

increase by 0.2 percentage points in 2020. At higher thresholds, the increase in poverty will be greater, and poverty will be based on the World Bank's national poverty line. Ukraine is expected to increase by 2 percentage points. Sustainable economic growth is needed to reduce poverty in the medium term.

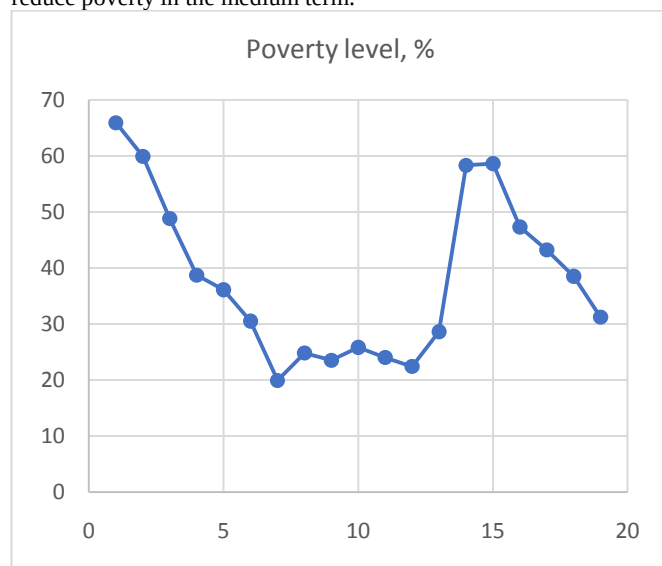


Figure 10. Dynamics of the poverty level from 2002 to 2020, % [6]

In the future, growth is expected to remain moderate in 2021 at 1.5%, and by about 3.7% by 2023. The outlook depends on the duration of the health crisis and reforms that address investment bottlenecks and ensure macroeconomic sustainability. Given the recent slowdown in reforms, fixed investment is not expected to reach pre-crisis levels until late 2022, and net exports (as demand for imports is recovering but export diversification remains slow) will continue to slow in 2021.

5. Conclusions

After analyzing the above, we summarize the main components of the cycle:

- 1) the industrial (technological) revolution passes to the next;
- 2) the introduction of scientific and technological progress leads to changes in the industry structure and the emergence of new achievements;
- 3) the emergence of crises of various scales is cyclical;
- 4) the dominance of the technological system is replaced by the following;
- 5) each new cycle brings new components associated with its features.

So, we have identified 4 crises in Ukraine for the period from 1990 to 2020. That is, on average we have one crisis in 5 years, which is a negative indicator, because the way out of the crisis also takes a long time. As the economy adjusts, new challenges emerge and other areas need to be restructured and rebuilt. On the one hand, this is positive, because more attention is paid to the affected sector and its complete recovery, and on the other hand it takes a lot of time, money (which the country has so little) and less directing funds to other areas, which affects other sectors economy.

During the onset of the 2019 crisis (coronavirus pandemic), the Ukrainian economy declined, but not as significantly as other developed countries. Entrepreneurs and all those employed in areas that require the physical presence of workers were affected. Instead, remote work has become especially relevant, the number of online works has increased, the IT sector has achieved great results and brought Ukraine to the international level on this indicator.

Although crises are constantly being analyzed and attempts are being made to prevent them, no one has yet been able to stop the new crisis prematurely. Therefore, this area needs further and more thorough research and development, namely bringing order and stability in all areas, which will prevent their sharp impression.

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Open innovation – potential, constraints and prospects

Borislava Galabova

University of Mining and Geology “St. Ivan Rilski”, Sofia, Bulgaria

borislava.galabova@mgu.bg

Abstract: *In the last decades innovations are defined as main priority. Overtime they become an instrument for achieving economic growth and social progress, increasing life standard and aiding in resolving difficult economic problems. The integration, globalization and concurrence define the goal of business organizations to become more innovated, adaptive and flexible in order to never stop developing, gain concurrence advantages and preserve their market share. They always have to take into consideration the constant changing conditions, the turbulent business environment and the increased consumer requirements for end products. In response of this necessity a new innovating model has been created and implanted, better known as open innovation. This relatively new modern concept shows significant potential for developing and by doing this it finds a place in the business practice. By proving its effectiveness through achieving positive results, the open innovation is established as a successful and useful model for innovation, outlining different perspectives and new routes for developing business organizations.*

Keywords: INNOVATION, OPEN INNOVATION, CLOSED INNOVATION, BUSINESS ORGANISATION, BUSINESS DEVELOPMENT, ECONOMIC INNOVATION PERFORMANCE

1. Introduction

Over the past decade, innovation has been identified as one of the main priorities. It is no coincidence that today they are accepted as a kind of vector of competitiveness and a logical path to the creation of added value. Over the course of business history, innovation has been established as a tool for achieving economic growth, increased living standards and social progress, helping to solve complex economic and social problems. Increasing globalization, integration and competition justify the aspiration of business organisations to be more innovative, open, adaptable and flexible in order to develop and protect their competitive advantages and to stabilise their market positions. Moreover, they should continuously address the global challenges, the changing socio-economic conditions, the turbulent environment and ever-increasing consumer requirements. As a result, it becomes necessary to take into realization ideas that come not only from internal, but also from external sources. It is the provision and accumulation of information from sources of different types and origins that plays a significant role in increasing their innovation capacity, which predetermines future financial and economic performance. To this end, they must constantly develop new or improved goods, services, business models, technologies and know-how, be fully ready for innovation and be open to generate ideas. Some of them strive to be innovative and "up-to-date" with the trends for creating, incorporating into and developing business ecosystems and platforms for open innovation and shared resources and are oriented towards sharing the innovation process. Others focus on using their own ideas, resources and research and development (R & D) potential. This closed and internally oriented innovation model delivers results under certain conditions and remains up-to-date and applicable. However, the turbulent economic development logically leads to the emergence of another open and rather externally oriented model, which finds a place in business practice, and this makes it a subject of increased research interest.

2. Prerequisites and ways to solve the problem

The main problem is related to the discovery of the potential and scope of open innovation, as well as to outlining the prospects for the innovation process. The aim is to explore this potential for creating favourable conditions for the growth and development of business organizations in the context of strong environmental dynamics on national, European and international level. The subject of this research is open innovation - as a modern concept and model for the conduct of the innovation process in business organisations. By comparative analysis and using a historical approach, a comparison is made between open and closed innovations and brings out points of contact and fundamental differences. Based on the use of analysis, summary, synthesis and analogy, some summaries of the scope, positive and possible negative aspects of

the open innovation model and its application from a business perspective are made. The emphasis is on the added value that the model could provide. Various courses are sought for questions about genesis, content and stages of the process and the potential of the open and closed innovation. Critical performance review and analysis of good practices become the basis for identifying guidelines for the development of business organizations and addressing serious issues, including ensuring competitiveness, added value, cost-effectiveness, growth and development.

3. Opportunities and potential of the open innovation

3.1. Open innovation: basics and conceptual framework

Historically, different theoretical views on innovation and models for the innovation process have been discovered. On the basis of their comparison, several main types of innovation and innovation process could be distinguished. The traditional innovation process is often described through a straight model in which innovation is series of stages starting from R&D and ending with a product sold on the market [5]. But deeper analyses paint a much more complex picture, it is difficult to argue that innovation is going through a series of strictly defined, successive stages [2]. Thus, compared to closed innovations, the non-traditional open model of innovation process is not a linear process and is distinguished by different genesis, content and stages.

The concept of open innovation was first developed and presented by Henry Chesbrough in the early years of the 21st century. It rests on the perception that in a world flooded by information, business organisations do not depend solely on their own research and should not rely solely on it to achieve efficiency and competitiveness and to preserve and multiply their customers. In order to be successful, they are forced to take advantage of a wider range of opportunities offered to them by external to the organisation resources and ideas [4]. Open innovation has been proposed as an entirely new paradigm for managing innovation and processes. According to this, the business organisations have opportunities to combine internal and external ideas as well as internal and external paths to market to advance the development of new technologies [4]. On this basis, the introduction and formalisation of the concept of open innovation aims in practice to distinguish it from the closed innovation created in a traditional way. In the past, this type of innovation was meant by different names, such as collective, partner, collaborative, modular and dispersed innovation. Since the beginning of the 21st century it has become popular as an open innovation, which marks the beginning of the construction of a comprehensive concept for this fundamentally different kind of innovation.

The concept of open innovation builds on the increased role of the external sources in the innovation process. Their growing role is also accompanied by an expansion of the organisation's R&D capacity, although this is not about internal capacity. There are different ways of accessing and benefiting from external resources, making it possible to acquire, absorb and use knowledge, ideas and concepts that are not a product of the activity of the business organisation itself. In this way, it gets access to external creativity. The business organisation has the ability to use technology transfer, shared resources, licensing, open source software and crowdsourcing, which are a field for the active flow of incoming and outgoing information flow. By comparison, the traditional and widely used innovation model in the last century is most often defined as closed because it concentrates and flows mainly within the organization. In order to be able to move smoothly from the closed to the open innovation model and to take advantage of its advantages and potential, business organisations must create, develop and establish an appropriate innovation climate by monitoring, analysing and exploiting these opportunities fully under the right conditions. In this way, adaptation becomes key to organisational competitiveness and business performance in the context of the set economic, social, political, legal, technological and environmental variables.

The essence of the concept of open innovation is based on overcoming and blurring organisational boundaries in order to generate ideas, develop and implement innovations. The communication process is intensified between users, suppliers, researchers, partner and industry organizations, non-profit organisations, even competitors whose behavior can be used as a barometer of the state, trends, attitudes and direction of business development. Opening up and using an external perspective on the process of generating ideas and turning them into innovations gives a new perspective and horizon to business organisations. The need for constant change – as an iterative process, and its effective management become the basis for the imposition of open innovation. On the other hand, the inability to have the organisational capacity to be large enough to ensure the progress of innovation processes is a reason to increase the tendencies towards opening up business organisations and to look for new opportunities for innovative development and management of change. Prerequisites for the imposition of the new open model create globalisation, integration and increased mobility of workers, the growth of the venture capital market and the increasing role and capacity of external suppliers. Business organisations face significant changes related to and resulting from external environment factors, including the emergence and dissemination of new technologies, accelerated technological transfer, major changes in economic, social, political, technical and cultural relations and links, the transition from mass to individualised consumption, increased competition along with cooperation and cooperation, shortening the life cycle of the product. The open innovation approach is the new frontier to which we need to focus on the innovation process, but changes, both cultural, organisational and institutional, which it implies should not be underestimated. The objective of its implementation is to reach stable market positions, followed by business development and growth based on innovation activity as a basic condition for increasing competitiveness.

Today low innovation activity and potential for innovation is a key feature, inherent both for the Bulgarian economy in its entirety and for a significant part of the business organisations in particular. Their technological level lags behind that of competitors, which outlines a vicious closed circle, leading to a further contraction of their innovation capacity and an impossibility of further growth and development. These adverse circumstances are indicative and relevant in the context of the need to "catch up" at the level of innovation and to align it with the other Member States of the European Union. The long-term trend that has developed over the years does not allow for a significant improvement in the market positions that Bulgaria has as a highly open economy, and has a negative impact on competitiveness. At the same time, the potential

for own research and development remains very limited compared to that of other economies. This raises a number of questions about the real and potential opportunities for innovation that business organisations have and how much capacity they have and tend to create and implement innovations in a more flexible way. Do their managers share the view that the openness of business organisations is the key to achieving added value, efficiency and effectiveness? Are they ready to transform, open their borders and work in broad collaboration with partners, building an open partner network? Whether their answers are positive or negative, industrial structures continue to change and acquire a network form, which completely changes the approaches to generating ideas, creating innovation and putting it into practice. Collaboration with external partners seems to be particularly important with reference to social, organizational, and ethical issues in the context of innovation [3, 6]. In today's global society, firms recognise they have much to gain from creating partnerships and engaging with the rest of the world [8, 9, 10]. A large number of practices fall within the scope of open innovation and are instrumentalized through platforms [7]. Their use is becoming increasingly popular and preferred because it allows the sharing of the innovation process, resources, ideas and solutions and the involvement of more participants.

3.2. Comparative analysis of the concepts of the closed and open innovation

Understanding the nature of open innovation requires comparing it with the traditional closed version. The search for the common and the different between the two concepts is the basis for analysis and evaluation of these different models.

The concept of closed innovation is based on the research and development of the business organisation itself. In this case, the ideas and solutions to problems are generated and developed without crossing its boundaries, which are poorly permeable. (Fig.1).

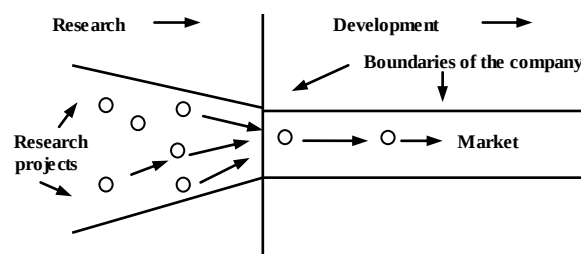


Fig.1 Paradigm of the closed innovation
Cresbrough, H. (2003). Open innovation: The new imperative for creating and profiting from technology. Boston, Harvard Business Press

As shown in Fig. 1, this type of innovation is a result of the efforts mainly of a particular business organisation and are a logical consequence of its investment and innovation activities. Innovation is therefore a function of its own research, financial and human potential. In order for the business organisation to make the most of R&D, all phases of the innovation process are deployed and carried out within its framework and on the basis of the use of internal resources, including human resources. If there is a need for further expertise, external experts are rarely attracted. In general, the main part of the R&D activity is carried out within the organisation by the internal experts involved in the generation and development of innovative ideas. Thus, the model for innovating from the beginning of the idea to its practical implementation is rather centralized and focused on the organization itself and its structures. In today's innovation context, significant organisational potential is needed in all its aspects, making it difficult for innovation processes to take place and slowing down the receipt of expected results, whether products, services, processes or business models. The researchers on the subject agree with the view that this is also the largest deficit

of the closed innovation model. Focusing mainly on the internal capacity and viability of the business organisation to create both novelty, utility and added value is equal to limited innovation opportunities that extend to the organisational capacity itself. Despite this major disadvantage, the closed innovation model also has advantages. It continues to work well and show results in certain circumstances and in certain areas of business. For a concrete business organization advantages originate from the relative independence from the external environment, partners and collaborators and their freedom to generate and formulate their own ideas and solutions to the problems without being strongly or entirely dependent on external sources of ideas and resources needed to the innovation activities.

The shortcomings arise from the fact that the knowledge generated is relatively incomplete and fragmented, as it is created within the organisation's boundaries and according to its capacity and resources, which are in any case limited. Regardless of its size and internal potential, no organization by itself has sufficient financial, human, material, temporal and information resources to solve the emerging complex theoretical and applied problems. Sharing resources and creating innovation based on cooperation are an objective necessity if the business organisation strives to achieve results and be relevant to realities. Finding realistic, feasible and effective solutions to such problems implies large-scale, long-term and costly development and research that requires significant capacity, pooling of resources and strategic management. For these reasons, closed innovation faces more and more barriers in its application and development. Problems seeking solutions are complicated, and solving them without multilateral cooperation becomes difficult, even impossible, and greatly becomes more expensive.

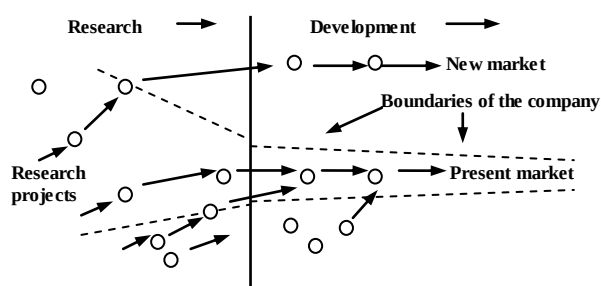


Fig. 2 Paradigm of the open innovation

Cresbrough, H. (2003). *Open innovation: The new imperative for creating and profiting from technology*. Boston, Harvard Business Press

The concept of open innovation is based on opening up the business organisation to the external environment. As shown in Fig. 2, ideas, views and suggestions of various direct or indirect actors in the innovation process begin to pass through its boundaries. Open innovation has been established in practice since the beginning of the 21st century and is particularly relevant in today's conditions. Trends of increasing opening up to consumers and their direct or indirect involvement in innovation generation process lead to their entry and enforcement into practice.

Open innovation is a result of diverse forms of exchange of ideas, ready-made solutions for creating innovations and cooperation in their creation together with various external organizations, including partner business organisations, universities, research institutes, units and centers, public sector representatives, freelance experts, spin-off companies and consumers. In case of open innovation both internal and external experts and collaborators are included. The organisation uses them to achieve certain results leading to innovations or improvements of an existing product, service, business process or model. The range of participants in the process should be wide in order to cover many ideas, solutions and proposals to overcome a specific challenge formulated as a problem. The open innovation concept also includes the active

presentation of knowledge by the company in the form of the sale of rights to use its intellectual property [1]. The aim of this model is to achieve innovation in the most active, flexible and decentralised way, innovation is gradually needed in practice, together with its different practical modalities.

Over the past decade, the list of organisations from different fields of activity using this approach in practice has become longer. This is no coincidence, as the assessment of organisational resources and opportunities leads to a re-appreciation of the constraints of the closed innovation and the potential benefits of opening, searching for and sharing resources and using them. The model acquires new reading and become even more actual in the current context related to the coronavirus pandemic (COVID-19), the crisis and recession, which are direct consequence of it. Cooperation between business organisations from different fields of activity becomes imperative and objectively justified in order to find solutions to the emerging problems and issues in all aspects of the economy and society. Given the adaptive, accessible and flexible model, open innovation shows potential to expand the value creation space. They can help build a positive image, defined by greater transparency and openness of the organization's activities.

3.3. Open innovation process

Chronologically the open innovation process goes through several main stages. First, it is predestined by the generation of a realistic and feasible idea related to a need, which is an initial stage for each innovation. A significant condition for starting is the existence of an unresolved problem for which there are objective and actual prerequisites and possibilities to be resolved in perspective and so the need can be met. The innovation idea should also be related to the achievement of a specific objective of the business organisation. It is defined by its potential and available resources through which to develop and become a finished product on the market. Secondly, it follows a stage of development and implementation of the idea, assessed as realistic, feasible and consistent with the objectives and restrictive conditions arising from the characteristic of the internal and external environment. Third, the process ends with the marketing idea, which has become a specific innovation product bearing the hallmarks of novelty, utility, value and value.

The creation of open innovation is a systematically ongoing process that has different stages and participants in each of them. In the first stage named conceptualization it is necessary to create prerequisites for establishing an organizational climate suitable for creating an open innovation. Often the stage of generation of the idea itself is most open and there is an opportunity to participate directly or indirectly a large number of participants. Within its framework, important activities are carried out: research planning, targeting, ensuring innovation infrastructure, organization of the team, allocation of roles, resources to carry out their activities and tasks and manage them. The first stage ends only when a comprehensive concept has been built and a work plan has been developed towards it. The conceptualisation phase should not be underestimated because it is the basis for moving to the next stages and therefore affects their results and starting points. Unlike closed innovation, during the conceptualisation phase of open innovation, it is necessary to plan and anticipate the normal flow of incoming and outgoing information flows from the point of view of business organisations, as well as to clarify the overall vision, purpose and way of achieving it. For this purpose, the necessary models and tools are developed, the competences are specified and the project is prepared. For the development stage, as a starting point, the results achieved from the conceptualisation stage shall be used. The third stage is the implementation. Within its framework, the system begins to "work" and the processes are carried out according to the planned in the conceptualization stage and the prepared project in the development stage. In this final stage, the most active exchange of information takes place between the business organization, stakeholders and its partners in the innovation process. By

implementation of some guiding mechanisms, innovation activities allow to go beyond organisational boundaries and achieve process efficiency. A significant difference between the closed and open model of innovation is found precisely in controlling the process at different levels and the degree of control. Closed innovation has significant control, concession and centralisation of resources, little interaction with the outside world and environment and impermeable boundaries. Compared with them, open innovation has significantly weaker control, weak concentration and strong decentralisation of resources, active interaction with the outside world and environment and permeable organisational boundaries. In general, the process of innovation undergoes a principled transformation - from individual becomes collective and from a straight becomes non-straight. It seeks a balance between cooperation on the one hand and competition on the other.

3.4. Challenges and constraints on open innovation and approaches to addressing them

Finding new partners and creating partner networks doesn't just bring positives. It also means more costs for the business organization concerned. However, the creation of a partner network and its expansion provides new opportunities for development and growth and revenue. In parallel, the new partners also provide additional skills and competencies in the direction of shared resources and expand the prospects for the business organization. In the current context, requiring all businesses to adapt to new realities and overcome the effects of the coronavirus pandemic (COVID-19), finding partners is facilitated by focusing on a common problem. This way, organisations can navigate the search for more new partners and types of partners. In this sense, the main challenges and constraints to open innovation stem from the need to transform business organisations and their orientation towards an open and multilateral innovation process, which also means a fundamentally new strategy for managing it. The lack of practice and experience in building and developing a partner network can also be attributed to possible challenges, because starting from scratch will involve additional costs and time to build it and the actual start of the innovation process. The issue of intellectual property and its protection is also challenging in regard of the changes in strategy and organisation needed in the transition to an open innovation model. Although these challenges and constraints are real. They can be overcome or reduced if appropriate management strategies, methods and techniques are implemented in a timely and effective manner.

4. Results and discussion

Opening up business organisations to the outside world and transforming models from closed to open ones is a fact. Proving its effectiveness in recent years, open innovation is necessary as a successful, useful and applicable innovation model, which is widely embraced first in developed and then in developing countries. A prerequisite for its entry are the wide range, flexibility and adaptability that the open model offers and which are necessary for the development of innovation activity in the face of significant dynamics and increased competition. Invariably, the current conditions require radical changes in the strategies, orientation, approaches and models of business organisations to the innovation process and their relations with consumers, partners and competitors. The search for ideas for solutions to consumer problems is no longer only a novelty, but is considered to be an objective necessity. Turning them into innovators is a key to the success of those business organisations that strive to be innovative, seek new paths for growth and development and increase their innovation capacity. The adoption of open innovation strategy, created on a broad and open basis, and its implementation give business organisations certain advantages: an opportunity to achieve greater added value and benefit for society and the individual consumer, greater consumer satisfaction and a more effective

innovation process. The interaction and exchange of ideas between many different participants gives a new look to the innovation process and expands not only its boundaries, but also the desired end effects of the development and implementation of innovations. The aim is to open new business opportunities and to increase the efficiency of the innovation process by reaching empty spaces and proceeding to their research and utilization. The main direction for development is the imposition of a strategy for opening the innovation process, if not fully, at least partially for certain areas of activity, goods, services, processes and models in order to make the most of the opportunities of the external environment and the potential of the concept of open innovation.

5. Conclusion

This analytical study is dedicated to the potential of the open innovation to create favorable conditions for growth and development of business organisations in the context of strong environmental dynamics at national, European and international level and to facilitate adaptation to economic, social, technological, technical and political conditions. Different perspectives are sought on the genesis, content and stages of the process and the potential and scope of open innovation compared to closed innovation. The aim is to study the potential for creating favorable conditions for growth and development of business organisations, as well as to identify the main challenges in the implementation of such open models. It is concluded that open innovation offers new business horizons, increasing the efficiency of the innovation process, reaching empty spaces and proceeding to their study and utilization. A key direction for business development is the imposition of a strategy to open up the innovation process, if not entirely, at least in part, to certain areas of activity, goods, services, processes and models in order to harness the opportunities coming from the external environment and to exploit the potential of the concept of open innovation.

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Conceptual model for assessing the digital maturity of the production system

Nataliya Koleva
Faculty of Management, Department IIIM,
Technical University of Sofia, Bulgaria

Abstract: The intensity of technology development that we have witnessed in recent years has changed the expectations and attitudes of customers, as well as their understanding of value, and is becoming the new leading factor in the development of the industry. A retrospective of industrial production shows that all stages of change and development that it has gone through are stimulated precisely by the desire to meet the demand, expectations and needs of customers. In this sense, industrial enterprises around the world are clearly aware of the need for change. They should review their current production and sales strategies and focus their attention and efforts on building dynamic production models that will allow them to continue to operate successfully in a highly competitive market environment and changing customer requirements. Digitalization plays a key role in this new scenario in which industrial enterprises must fit in today. Digital technologies and the opportunities they create are the main driving force for the necessary radical change, which companies must rely on in order to increase their efficiency and, respectively, to maintain their competitiveness. This publication presents a conceptual model for assessing the digital maturity of the production system of the industrial enterprise.

KEYWORDS: INDUSTRY 4.0, DIGITALIZATION, SMART MANUFACTURING, DIGITAL MATURITY, PRODUCTION SYSTEM

1. Introduction

Creating a production model in accordance with the requirements of digitalization is not an easy task and requires a good understanding of the main issues, trends and potential that digitalization creates. According to the author, it is the good understanding, on the one hand, of the requirements and problems / challenges that digitalization poses to industrial enterprises, and on the other hand, that the opportunities it opens for their development should serve as the basis on which to build. Overall concept for digital transformation of production.

In recent years, the problems associated with the processes associated with the digital transformation of business are discussed in depth in the scientific and business circles. The digital transformation is at the heart of the Fourth Industrial Revolution or the so-called Industry 4.0. The technological potential of Industry 4.0 has a crucial role in increasing the efficiency of the functioning of the production subsystem in particular, as well as the enterprise as a whole [1, 2, 3, 4, 6, 7 etc.], allowing to improve the ongoing production and operational processes through the use of high-tech solutions (for example: 3D - printing allows for a quick response to changes in the design of the product, which increases the flexibility of the production system Internet sensor networks make it possible to monitor the implementation of production processes in real time, machine learning software systems allow for predictable maintenance, monitoring, control and optimization of production processes, etc. under).

Businesses in different industries are moving at different speeds on their digital transformation [1,3]. They face a number of difficulties of financial, technological, social nature, etc., which manifest themselves and dominate with varying strength given the specifics of the activity, as well as given the attitude, motivation and will of the workforce to adapt to the new production environment, which is imposed by Industry 4.0.

One of the main questions that arises in this regard is: "What is the level of digital maturity of the production subsystem?" In the author's opinion, finding an answer to this question is crucial for the implementation of effective digital transformation of production, as enabling businesses to:

- to make an objective self-assessment, both of their capabilities and of the progress made in terms of design, organization and management of production processes in a digital environment;
- identify Key Performance Indicators (KPIs) in terms of process digitization;
- to build a clear strategy to follow in the process of digital transformation of production.

2. Model for Assessing the Digital Maturity of the Production System

The author's thesis is that for the implementation of effective digital transformation of industrial production, attention should be focused on optimizing the physical (production/operational) processes and increasing the efficiency of the production system as a whole.

The essence of the model proposed here consists in the analysis and assessment of the situations in which the production system of the enterprise may find itself in terms of the requirements for its digital transformation. These situations are formed under the influence of a wide range of factors, which are generally related on the one hand to the specifics of the physical design of the production system and the current way and efficiency of its functioning, as well as the attitudes of human capital to change imposed in the process of transformation.

The assessment of digital maturity of the production system can be represented by a four-step model, which is shown in fig. 1. Each of the presented levels represents a different degree of digital maturity of the production system of the Industrial Enterprises (IE).

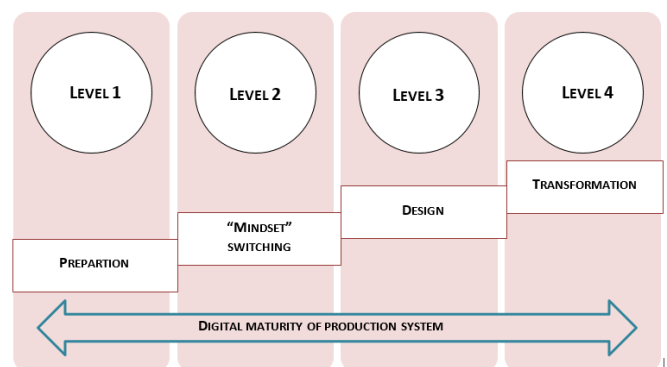


Fig. 1. Levels of digital maturity of the production system of the IE

Level 1: Preparation

At level 1, enterprises and in particular senior management are already beginning to realize the importance of digitalization and the need for serious and in-depth study and acquisition of knowledge and skills in this area in order to lay the foundations of the process of digital transformation of production. At this stage of their digital maturity, enterprises must have a clear idea of the scope of the process of transformation of the existing model of functioning of the production system. As here, it is important to emphasize that digital transformation should be considered on three main levels, namely: (1) technological, (2) organizational and (3) cultural [5]. In other words, at this stage it should be realized that the digital transformation does not simply mean the introduction of new

technologies to support and optimize the functioning of the production subsystem. Due attention should be paid to the construction of the so-called digital or cloud culture, as well as to the way of organizing and managing the processes.

A questionnaire can be used as a tool for level 1 assessment, and for passing this level companies should have a clear understanding of:

- the main reasons that impose the digital transformation as vital for their survival in the modern network economy;
- current technological trends.

The main question to be answered at this level of digital maturity is: "Why things should be done in a new and different way?" The answer to this question must be sought in the understanding that the application of new technologies will not only change the efficiency of the production system and customers' understanding of "value", but will significantly affect the way people work in the company.

The author is of the opinion that the awareness of the need to change this level is crucial for "switching" to a new way of thinking (digital way of thinking), which already provides the potential to move to the next level of digital maturity.

Level 2: "Mindset" Switching

At this level 2 of digital maturity, it is very important for employees from different levels of government (strategic, tactical and operational) to build a new way of thinking. It is necessary to achieve "thinking outside the box". I believe that this is one of the most important factors for a successful digital transformation.

Indeed, the digital transformation is the subject of serious changes in terms of the role of man and his contribution to the efficient functioning of the production subsystem, as well as to the enterprise as a whole.

As a result of digitalization, we are witnessing a significant change in the division of labor between humans and machines, and the following features should be taken into account:

(1) the machines / robots acquire an increasing degree of importance for the functioning of the system, and also become more autonomous / independent decision-making from the lowest level / in the implementation of the tasks / operations assigned to them;

(2) the place and contribution of the human factor to the functioning of the system is substantially changed;

(3) human-machine interaction moves to a new "intelligent" level;

At first glance, it may seem that the responsibilities and workload of people are reduced as machines take over a significant part of their functions. It should be borne in mind, however, that the cyber-physical production environment is characterized by a high degree of technological complexity, which will increase, and this in turn implies the performance of tasks by people / workers in the process of interaction with the system changed and to some extent complicated. The cyber-physical system with which the person will interact directly imposes the need to hire specialists with interdisciplinary knowledge. Given what has been presented so far, it can be said that for the effective transformation of the production system into a "cyber-physical production system" it is important that employees from all hierarchical levels of the organizational and management structure are open to change and have the attitude, the will and motivation to adapt to new roles and the new work environment, as well as to develop skills for continuous interdisciplinary and lifelong learning...

It should also be noted that management should expect the development of some barriers that would make it difficult to pass to level 2. The following may be such barriers:

- workers' resistance to change;
- striving to preserve the style of work adopted so far;
- fear of changing duties and responsibilities;
- fear of changing priorities;
- "we don't need that"
- "this is not applicable to our conditions"
- etc.

The listed barriers should not be ignored, because such behavior on the part of employees would significantly increase the levels of risk and ultimately the transformation would be ineffective.

This connection, in order to successfully pass this level of digitalization, to work actively in the direction of motivating and involving all employees in the transformation process. Every employee must recognize themselves and have a clear understanding of their place in the enterprise and their contribution to the process of digital transformation.

At the output of this level 2 it is necessary:

- to have a new type of organizational culture - cloud culture, which helps to "switch" to the new way of thinking (digital thinking);
- to have a developed policy to support the adaptation of the workforce to the new production environment;
- thanks to the latter, the levels of resistance of the labor force should be minimized;

The toolkit that is proposed to be used for this purpose is again a questionnaire to examine the attitudes of the workforce towards the forthcoming changes.

Level 3: Design

During level 3, companies should start building the vision for creating a digital production model. Successful level 3 coverage involves going through the following phases:

- Phase 1: Analysis

In this phase, the current state of the enterprise should be analyzed in terms of:

✓ The elements of the market environment

Here it is necessary to study the expectations of customers and trends related to their understanding of value. In order to establish the attitudes of the customers in the modern market conditions, a survey can be conducted. Its results will be of paramount help in orienting producers to the expected value of products / services for which customers are willing to pay.

Next, competition and the progress it has made in terms of digital transformation should be examined here. This will enable manufacturers to establish how they are positioned in relation to their competitors and to predict how the new digital production model could contribute to improving the market position, for example.

✓ The readiness of the workforce to the requirements of the digital production environment

As already mentioned, the participation and motivated assistance of all employees in the company (from the strategic, tactical and operational level) is one of the key factors for the realization of a successful digital transformation of production.

In fact, it should be noted here that the process of bringing the workforce ready for the changes caused by the digital transformation begins at level 2, where it is expected to build a new type of organizational culture and, accordingly, a new way of grinding.

In level 3, the relevant deficits should already be analyzed as competencies of employees in connection with, for example, the need to retrain them due to taking a new job / position or to be further qualified in connection with changes in the way they perform their previous tasks. Due to this analysis, appropriate employee training should be planned in phase 2 of this level.

As here, it should be emphasized that digital transformation does not only need IT specialists. In fact, operations management professionals, for example, are becoming quite valuable to businesses.

Table 1 presents an example form for analyzing the competencies of employees in relation to digitalization.

Table 1 Form of competence analysis

Competence	Type of Competence			Applicability
	Basic	Key	Expert	
Competence 1	x			
Competence 2	x			
Competence 3			x	
...		x		
Competence N			x	

✓ *The readiness of the digitization processes*

Bringing processes ready for digitization is crucial for carrying out an effective digital transformation of production. In the author's opinion, the potential of the Lean Manufacturing concept can be used for this purpose.

✓ *The technological potential for ensuring the requirements of digitalization*

Here it is necessary on the one hand to make a study and acquaintance with the new technologies and the possibilities to integrate them into the new production model, and on the other hand to establish what technological basis is currently available and how it can be adapted to the requirements of the new digital production model. Research can be used again as a tool / marketing, literature, good practices... /, in order to identify the latest technological trends.

- Phase 2: Planning

Based on the results of the "Analysis" phase, here in phase 2 - "Planning" it is expected to develop a comprehensive strategy for the transformation of the existing production model into a digital production model. In fact, here producers need to have a clear idea of the scope of work related to bringing production in line with the requirements of digitalisation. The project management toolkit, namely the Work Breakdown Structure (WBS) approach, can be used for this purpose. The main groups of works (Work Packages / WP) of the project for digital transformation of production are the following:

✓ *WP 1: Development of a plan / program for building the necessary competencies of employees in connection with the digital transformation*

As a starting point for the development of the program for building competencies and organizing the respective trainings of the Project staff, a completed competency map will be used in the "Analysis" phase. Of course, the individual areas in which training will be needed should be prioritized according to the needs of the first time. The latter is valid especially with regard to the training of employees at middle and operational levels of management.

✓ *WP 2: Designing the future state of the production system using the Value Stream Map/VSM approach*

Here the value added map for the current state of the production processes is used as initial information, as in the design of the future state all activities that do not add value are removed (minimized).

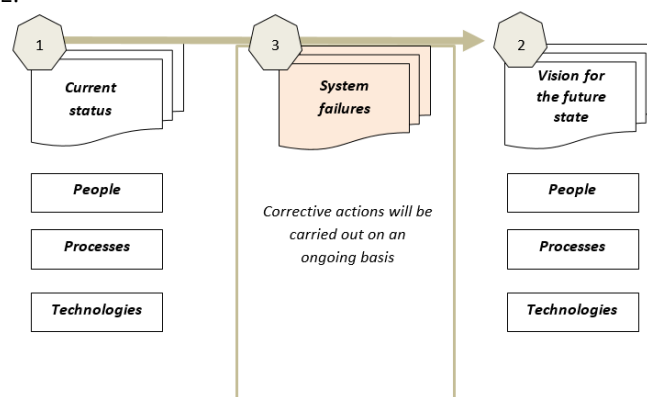
I support the thesis that in order to transform into "Smart" production processes must be "Lean" ,,

✓ *WP 3: Designing the requirements for the technological and information infrastructure necessary for the digitalization of production*

Based on the analysis of the current technological potential of the production system, a vision should be developed for the need to master and implement new high-tech solutions. It is necessary to develop a plan for the implementation of new technologies so as not to disrupt the current functioning of the system. Next, the necessary documentation should be prepared, which concerns the

individual elements of the production system. Its data should be accumulated in the central server of an embedded system.

At the exit of this level should be built the so-called "Roadmap for digital transformation" - an example of such is presented in Fig. 2.

**Fig. 2.** Example form of a roadmap for digital transformation

Level 4: Transformation

At this level of maturity, enterprises, based on the diversified roadmap for digital transformation, are currently starting to implement their missing practices. In other words, at the level of transformation, the team engaged in the implementation of the "Digital Transformation Project" must deal with the sustainable implementation and implementation of ideas, programs and procedures developed at the level of "Programming". Of course, at this stage they should have already realized that transformation is a continuous process of self-analysis and improvement.

It is important to note that for the successful implementation of the process of digital business transformation it is necessary to continuously monitor and analyze how the role, efforts and incentives of human resources involved in the transformation process have contributed to the management of change, which occurs at each of the maturity levels. Continuous monitoring of the transformation process will make it possible to identify the main positive and negative factors that have influenced the transition of construction in the enterprise of a digital production model.

3. Conclusion

Building a digital production model is one of the main strategic decisions that the company must make and which largely determines its potential to meet the specific requirements of customers. This publication presents a concept of a model for assessing the digital maturity of the production system.

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Anti-crisis policy of bio-enterprises in conditions of COVID 19 through innovation

Alexieva-Nikolova Valentina¹, Valeva Katina²,
Business Faculty – University of Food Technology -Plovdiv, Bulgaria,
valentina_nikolova@abv.bg¹, tomika_888@yahoo.com²

Abstract: The COVID-19 pandemic is one of the biggest challenges facing modern society and business. In a dynamic crisis situation such as the current one, the forecasts for the impact of COVID-19 on the world economy and the development of individual business structures are changing. Business is facing more and more difficulties, and uncertainty and uncertainty are increasingly taking over global and economic life. The implementation of an anti-crisis policy based on innovation is becoming key to tackling the pandemic. The main objective of this study was to demonstrate the challenges of bio-enterprises during corona virus pandemic in Bulgaria and the opportunities they can draw to create innovation. A number of research methods and techniques for the tertiary and empirical part of the work were applied in the aim of realizing the objects and goals of the research – economical, statistical, mathematical, descriptive, comparative, monographic, graphical, questionnaire survey, etc. Initial contact and other basic information about all organic producers are collected from the official register of the Ministry of Agriculture and Food of the Republic of Bulgaria - a database of producers, processors and traders of organic products and food produced in organic production in a way that maintains such an up-to-date database. The analysis is based on data processing by 234 surveyed representatives of bio-enterprises from all sectors of the bioeconomy in Bulgaria. The data analysis result shows that many small and large businesses are suffering challenges and this unprecedented coronavirus crisis has caused destruction for many businesses in the globe and it is challenging to survive with reduced revenue, jobs lost and life slowing down and weak marketing performance even difficult to keep a calm head and their business alive. To support these businesses the government should use different mechanisms by cooperating with wealthy peoples and other non-governmental organizations. Besides, the bio- business owners should manage expectations and communicate with staff, suppliers, banks, and customers throughout this coronavirus frightening. Reduce expenses, be open to their employees about their finances and keep marketing, use different alternatives to deliver their product and recover from the crisis. The changes in the production and economic activity as a result of the imposed measures for limiting the infection have been studied; the main risks threatening future development and the type of anti-crisis innovative decisions taken by management.

KEYWORDS: ANTI-CRISIS POLICY, CRISIS, BIO-SECTOR, INNOVATION

1. Introduction

The bio-sector in the Republic of Bulgaria has a very high economic and social significance, since it has a substantial share in creating the gross domestic product and employing a large number of people [1]. In 2018, bioeconomy accounted for 11.9% of the GDP, which is largely the result of a fertile soil and quality natural conditions for agricultural production. According to the National Statistical Institute of the Republic of Bulgaria, 680,000 people are employed in bioeconomy, or 21% of the total workforce in the country[2]. In 2018, bio-production accounted for 19.4% of Bulgaria's total exports and generated a surplus of \$1.4 billion, \$130 million more than in 2017 (mainly due to increased exports of processed fruit and vegetables).

The successful bio-business depends on a large number of factors, but the following are the most significant: the yield and quality of their products, the prices of their products, and, of course, the decisions made in order to manage the bio-companies more efficiently [3,4].

Nowadays, consumers of bio-products around the world are demanding a better quality of products, which represents a major market challenge. Achieving quality in today's conditions requires the development of a competitiveness strategy that is based on innovation and quality [5].

The subject of research is the analysis of the impact of innovation and product quality on anti-crisis success of bio-companies in the Republic of Bulgaria. The main goal is the need to provide new knowledge in the field of innovations and quality of bio-based companies with the aim of achieving sustainable success.

2. Literature review

In the modern scientific literature there is a great variety of definitions of the concept of politics, but as Fotev G. notes, "none of them is satisfactory." life:

1. According to the target spheres of the societies, the policy finds application in the economic, social, scientific-technical, military, etc. areas;
2. According to the direction or scale, as internal and external;
3. According to the content and character, as progressive, reactionary, scientifically substantiated;
4. According to the subjects, such as the policy of the global society, the state, the enterprises, etc.

In the field of economics, politics is associated with a certain course of action, adopted and followed by a government, political

party, organization or enterprise, relating to the production, distribution and use of income, wealth and goods [1,5].

From the enterprise's point of view, the policy reflects the management's idea of its goals, strategy and culture, expressed in written or unwritten rules for managing the activity, which are shared by both the company's staff and its business partners. A well-formulated policy predetermines to the greatest extent all the subsequent actions and behavior of the enterprise - from the overall corporate strategy to the actions of an operational nature.

Crisis is an inevitable phenomenon in a market economy and a globalized world. In 2020, we witnessed an unprecedented health crisis affecting all economic sectors. Organic enterprises have not been spared the global problem [6,7,8].

The implementation of anti-crisis policy, as part of corporate policy in enterprises involves the analysis of certain key issues related to the specifics of the crisis, the content of anti-crisis programs, the role of experts in implementing anti-crisis policy and defining thematic fields to study anti-crisis policy in the specific enterprise or industry [9,10, 11].

A crisis in an enterprise is a condition caused by factors that have the potential to cause urgent problems in its economic, social and financial development, requiring immediate intervention to solve them.

For the individual enterprise, the crisis situation is defined as a complex set of problems, which is interpreted as a threat to its survival or as a potential opportunity for its future development. It has the following features:

- Disturbance of the balance of the enterprise due to the influence of direct and indirect factors, which in the conditions of crisis are stimulating, limiting or holding back its development [12,13].
- Weak or no possibility for the enterprise to adapt to the new conditions caused by the crisis, ie it operates in conditions of high risk and uncertainty.
- Continuous increase of unresolved problems and various accidental events that disrupt the normal functioning of the enterprise.
- Increasing the insecurity, dissatisfaction, worries and fears of various employees, customers, consumers, shareholders and others. business partners of the enterprise and the formation on this basis of negative and neutral perceptions about it.
- Introducing additional difficulties in collecting, processing and analyzing information. On the one hand, there is a constant increase

in information flows, and on the other hand, information about crisis events is incomplete, not always reliable and is not a good basis for correct and reasonable decisions [14,15].

- A mandatory element of crisis management is feedback - the company analyzes internal changes as a result of the crisis to determine its future behavior.

- Extremely destructive effect on the financial condition on this basis - attributing guilt and seeking responsibility.

- The time for immediate communication reaction, research and planning is short, and the risk of anti-crisis management to deteriorate the company's image is high.

- Need to control the situation from the very beginning by adapting, controlling and regulating, ie. to increase the influence of development stimulating factors and to reduce the restraining and limiting factors of development.

- Public relations (PR) specialists occupy leading positions in crisis management, especially for companies in high-risk industries (food, chemical, pharmaceutical, etc.). They develop specific communication programs for the sensitive environment of employees, consumers, shareholders, distributors and the media, especially if the crisis arouses lasting interest. PR is an important tool for protecting the interests of the company's business through the two main strategic assets - reputation management and marketing PR.

In its development, the crisis, as a phenomenon in the enterprise, goes through several stages:

1. Latent (hidden) period. At this stage, the preconditions for a crisis are maturing, but not yet manifested externally.

2. Crash period. During this period, all contradictions quickly escalated, as a result of which the dynamics deteriorated sharply. The stability of the enterprise is violated.

3. Period of crisis mitigation. At this stage, prerequisites are created for overcoming the crisis, providing a temporary balance in the enterprise.

4. Period of exit from the crisis. Every corporate crisis has an end.

The prospect of mitigating its negative impact, overcoming the crisis and even using it as an incentive for development depends on the timely anticipation of the crisis and its adequate management.

Of particular importance for **increasing the effectiveness** of the anti-crisis policy of bio-enterprises is the development of sound concepts related to the nature, features, goals and objectives of crisis management. The most important of them that address these issues are the following:

- **First concept** - considers anti-crisis management as "management of the enterprise in a financial crisis." It reduces anti-crisis management to the adaptation of traditional principles and methods of enterprise management in the conditions of financial crisis.
- **Second concept** - considers anti-crisis management as a system of measures aimed at bringing the company out of its crisis.³³ This understanding of anti-crisis management of enterprises is one of its main functions, but not complex enough. The reason is that it does not include functions such as - development of means for monitoring and prevention to prevent the causes that led to the crisis, as well as measures to limit and eliminate the negative consequences of it.
- **Third concept** - defines anti-crisis management "as the elimination of its insolvency (or recovery of its solvency)."³⁴ This wording is too narrowly defined and reduces the definition to one of the main tasks of anti-crisis management - restoring the solvency of the enterprise. It should be noted that this is a priority, but also a major goal.
- **Fourth concept** - formulates as the main goal of anti-crisis management bankruptcy prevention.³⁵ In its economic and legal sense, bankruptcy is the final and irreversible phase of liquidation of the enterprise. In our opinion, not all forms of crisis generate bankruptcy.
- **Fifth concept** - considers the system of anti-crisis management of enterprises as a special type of strategy - "anti-crisis management strategy"[16,17]. Reducing anti-crisis

management to a functional strategy in the system of its strategic management makes the principle of its complex nature meaningless [18].

The presented characteristics and analysis of the basic concepts show that in its content, anti-crisis management of enterprises is a process of preparation, adoption and implementation of management decisions to prevent financial crises, their successful resolution and minimization of their consequences [19].

Effective crisis management requires an active corporate innovation policy. It is implemented through innovation strategies including the development of innovation programs and projects.

From the point of view of bio-enterprises, the policy reflects the management's idea of its goals, strategy and culture, expressed in written or unwritten rules for managing the activity, which are shared by both the company's staff and its business partners. A well-formulated policy predetermines to the greatest extent all subsequent actions and behavior of the enterprise - from the overall corporate strategy to the actions of an operational nature.

In this regard, the **anti-crisis policy** of bio-enterprises can be defined as a system of rules, principles and frameworks (restrictions) for crisis management. The main goal is to choose a risk management mechanism that has the potential to cause a crisis in order to maintain a balanced economic situation of each business unit in the bio-sector. In order to undertake an adequate anti-crisis policy, an up-to-date review and assessment of the situation is required at both macro and sectoral levels.

The environment in which the bio-sector operates can be represented by the data of the IMD World Competitiveness Yearbook 2020. The data show that the Bulgarian economy continues to grow, but is far from developing its full potential. In 2020, Bulgaria remains in 48th place out of 63 countries, as it was in 2019. This is an improvement of seven positions compared to 2015, but worsening compared to 2009 (38th place). The Bulgarian economy continues to be among the most uncompetitive in Europe, and the long-term factors that determine competitiveness remain underdeveloped (see fig. 1)

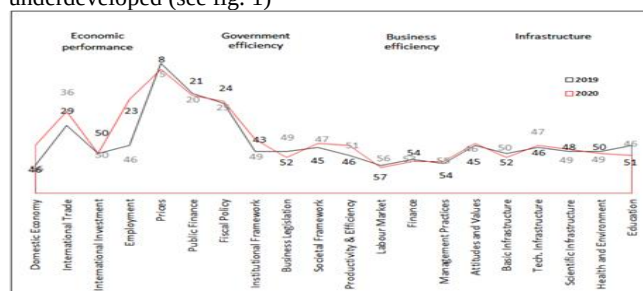


Fig. 1. Competitiveness of the Bulgarian economy

Source: <https://csd.bg/events/event/bulgarias-international-competitiveness-2020/>

According to the National Statistical Institute, after the large decline in the overall business climate indicator in the country for 2020, in January 2021 the data show an increase of 6.9 points compared to December 2020. The growth of the indicator is registered in all monitored sectors - construction, retail and services industry, including bio-industry. (Fig.2)



Fig. 2. Dynamics of the indicator general business climate in Bulgaria

Source: <https://www.intellinews.com/easing-of-covid-19-wave-pushed-up-bulgarian-business-climate-indicator-in-january-201542>

3. Methodology, research and discussions

The analysis was prepared mainly on the basis of survey, discussions and interviews with experts and organic producers from Bulgaria. Initial contact and other basic information about all organic producers are collected from the official register of the Ministry of Agriculture and Food of the Republic of Bulgaria - a database of producers, processors and traders of organic products and food produced in organic production in a way that maintains such an up-to-date database. A total of 234 organic producers from different sectors of the bio-economy were surveyed during the period of April -December 2020.

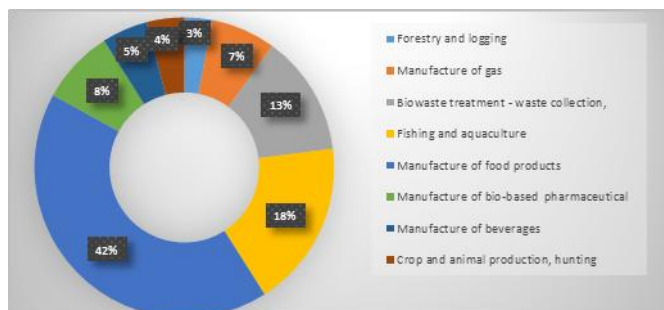


Fig. 3. Share of respondents from bio-sector in Bulgaria

A questionnaire was made based on the experience of the 35 experts from the above fields to determine which issues are important for further research. Based on the findings presented in the literature review, based on the available literature (domestic and foreign), and based on specialized works in this field a selection of questions for the poll have been selected.

The questions were created and in accordance to the ISO 9001:2005 and ISO 9004:2009 standards in cooperation with the mentor. Based on the analysis of the previous theoretical analysis a Basic system model has been created, "Impact of innovation and quality in agriculture on the sustainable success of agriculture" (figure 4).



Fig. 4. Model 1- The impact of innovations and quality in bio-enterprises on the anti-crisis success

Some hypotheses have been set on the basis of theoretical research. A general or zero research hypothesis has been set, which reads as follows:

H00 – The level of innovations and quality of bio-products significantly affects the level of anti-crisis success of bio-based enterprises.

The general – zero hypothesis will be proven by analyzing the auxiliary hypotheses, as follows:

- H11 - The level of innovations of bio-products significantly affects the level of quality of bio- products.
- H12 - The level of innovations of bio-products significantly affects the level of anti-crisis success of bio-enterprises.
- H21 - The quality level of bio-products significantly affects the level of innovations of bio-products.
- H22 - The quality level of bio-products significantly affects the level of anti-crisis success of bio-based enterprises.

Expert research was conducted on a sample of 35 experts on the territory of the Republic of Bulgaria (university professors, colleges, employees in public administrations at the position of bio-advisers, staff employed at institutes relevant to the field of research) in the period from 1 April to 1 December, 2020. An analysis of the profile of the respondents was carried out, the reliability of the elements of the set system model was established,

and the benefits and justification of the research, the factor analysis of the model, and the correlation and regression analysis of the model were calculated.

Following the analysis we can conclude that the level of innovation of bio-products related to the innovative behavior and innovative business practice of an bio-enterprises as well as the quality of customer relations and quality of the bio-product of an bio-enterprises itself affects the development of possibilities of anti-crisis success.

A study regarding the changes in the activity of enterprises after the introduction of emergency measures to overcome the Covid crisis is presented in fig. 5.

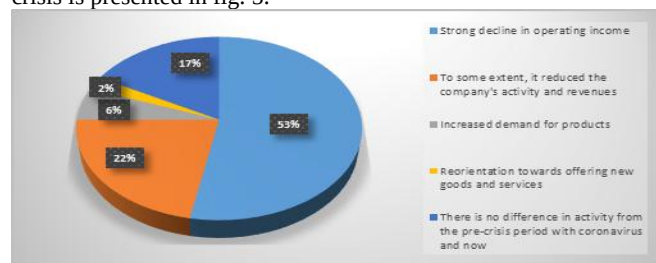


Fig.5. Influence of Covid 19 on the activity of the bio-sector

The data show that in 53% of the respondents, the income from the activity has sharply decreased. Revenues decreased by 22% to some extent. At 6% there is an increase in demand for company products / services. 2% of the respondents had to reorient themselves in offering other goods / services. In 17% of the respondents there are no changes in the activity before and during the crisis.

In Fig.6. the biggest risks for 2020 that the bio-sector shares are presented. As the biggest risk for the activity, the bio-enterprises point out - problems with the working environment, caused by the health crisis.

World and Bulgarian economic history teaches that companies that continue to invest in innovation during a crisis do better and outperform their competitors in the post-crisis recovery period.

The study showed that in the last year nearly 50% of bio-enterprises in Bulgaria have invested in the implementation of innovations. Just over 25% of respondents have refrained from innovation, but plan to launch an innovation project next year. If everyone succeeds in realizing their intentions, this means that for the period 2020-2021, nearly 75% of bio-enterprises in the country will innovate.

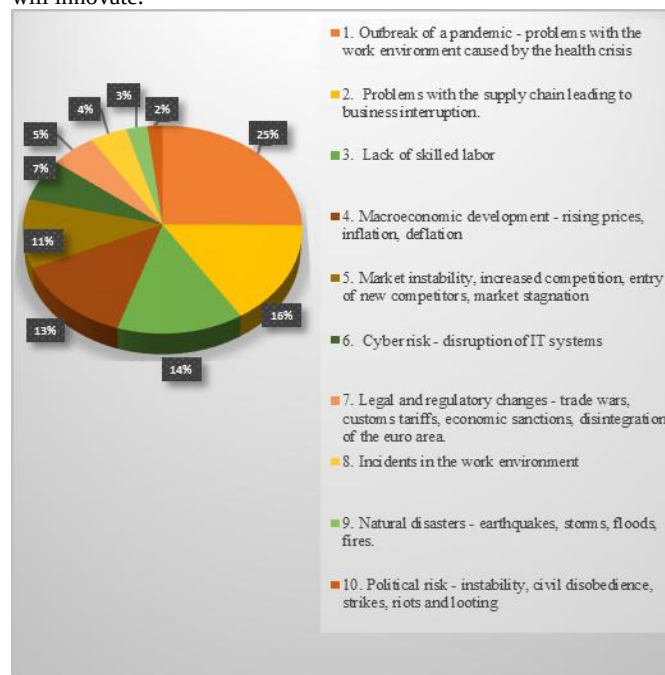


Fig.6 Main risks for the bio-sector in 2020

The share distribution of the types of anti-crisis innovative solutions, which were implemented in 2020 by the bio-sector in Bulgaria is presented in fig. 7.

The share of organizational and managerial innovations prevails, expressed in changes in the organization of work in 48% of respondents.

9% of the respondents introduced product anti-crisis innovations.

The share of marketing anti-crisis innovation solutions is large - in 40% of the respondents. They are expressed in introduced online sales (at 13%), changes in sales (at 15%) and introduction of new marketing approaches in the activity.

Only 3% of the surveyed organic companies have managed to automate the production process.

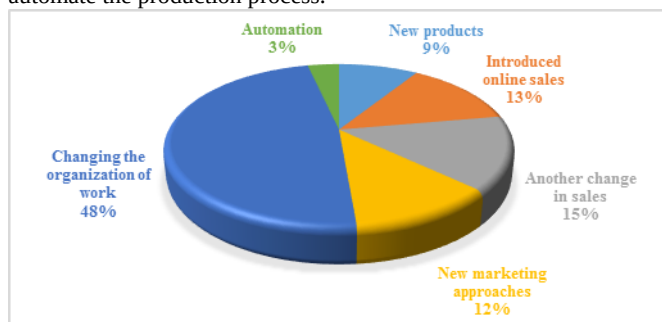


Fig. 7. Anti-crisis innovation solutions

4. Conclusion

Based on the research we can conclude that there exists a big influence of innovation and quality on an anti-crises success of bio-based enterprises in the Republic of Bulgaria. In order to achieve a sustainable level of success of bio-enterprises in the Republic of Bulgaria it is necessary to conduct constant education programs about the importance of innovation as well as encourage the aspiration for innovative behavior and business practice and the importance of investing in innovation and improving the process of production. The support of the state and the department ministry has a crucial role, through the support for introducing new technologies in enterprises from bio-sector, subsidizing the necessary materials for bio-enterprises, providing the necessary funding for constant education of bio-entrepreneurs and owners and exchanging the practices with bio-companies from the surrounding countries.

Innovative behavior of bio-enterprises could also be achieved through the support for new ideas, collecting ideas from external sources through encouraging business partners to create innovations and through a clearly defined strategy of introducing innovations and innovative management practices

Analysis of the set research models has shown that sustainable success of an agricultural holding could be achieved through the development of cultural behavior which supports creation and development of new ideas, funding innovative activities, through learning and mastering production practices, with a flexible strategy and encouragement of business partners to participate in creating innovation. Besides the previously stated, by setting the goals and politics of quality, determining and understanding the demands of the customer, fulfilling their demands and establishing communication with them with the goal of achieving feedback about the quality of the product we could, without a doubt, achieve the sustainability of holdings in the R. Serbia. Innovative business of individual agricultural holdings could be achieved by following the modern solutions in agriculture through the improvement of production by using innovation. Innovative behavior and business of individual agricultural holdings through the establishment of a quality customer relationship and the development of quality also affects the achievement of sustainable success of individual agricultural holdings by fulfilling the expectations coming from its surroundings and through the establishment of strategies based on the needs if interested parties.

To ensuring business continuity and providing stability to the stakeholders who rely on us has been a priority since day one of the

crisis. This implied offering flexibility and reliable development platforms, so that technical bodies could continue their standardization work online, in a safe, responsive and well-integrated working environment. While the agility and resilience demonstrated by the staff and technical experts has been impressive, the crisis has clearly increased the need for flexible and responsive standardization processes. Bulgarian Ministry of Agriculture, Food and Forestry will therefore invest more in the development of user-friendly digital platforms for the efficient, collaborative authoring of standards online, making the best use of modern technologies to enable virtual standards development, while increasing the speed of development. These measures embrace similar initiatives undertaken at the international level at ISO and IEC and reflect Bulgarian policy commitment to fully embrace digital standardization.

It is also necessary to pique the interest in innovative activities of those bio-companies owners not overly open for innovation. This could be achieved through establishing the bio-business centers whose priority would be to inform the owners about the modern production methods, invitations and fund allocation or donation programs, tax stimulations, invitations for cooperation with other participants, educational programs, interregional cooperation and cross-border projects and other actions which would benefit the local bio-enterprises.

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Training in mechanical engineering technology – innovation with traditions in the future

Petar Rachev

Faculty of Mechanical Engineering¹ – University Gabrovo, Bulgaria,
petar_ra4ev@abv.bg

Abstract: In this topic the model of training in Mechanical Engineering Technology and its similar technological disciplines for the period of the last 30 years in TU-Gabrovo is considered. The shared experience can be discussed and used in education in technical universities and vocational high schools.

KEYWORDS: MECHANICAL ENGINEERING TECHNOLOGY

1. Introduction

The model of training in technology of mechanical engineering (TME) and its similar technological disciplines covers a period of the last 30 years at TU - Gabrovo.

1. Results and discussion

From the very beginning it relies on continuity and continuation of the activity of Assoc. Prof. Dr. Eng. S. Stanchev on the existing curriculum, but begins to work consistently on its own model of education entirely in technological disciplines or one of the most important areas, which shapes the engineer. In 1995, a block diagram of the training in the specialty "Precision technique" (PT) was proposed, in which the technological disciplines occupy 270 hours or 7.4% and part of specialized training (Fig. 1) [1]. The main disciplines in the bachelor's degree are TME and Technology of Mechanical Engineering and Precision Technique (TMEPT), but the technological disciplines include Automated Production Planning and Management (APUP) (1996), Engineering Logistics (IL) (2000), Technology Oriented Design (TOD) and System Design (SD), which developed curricula with abstracts for the specialties Mechanical Engineering and Precision Technique (MEPT), Technique and Technology for Environmental Protection (TTOEP) and Business Administration (BA) - distance learning and characteristics to them in 1995/6 years. The training takes place in 4 stages in classroom employment in the disciplines TME and TMEPT from 150 hours (90 + 60) and project. New topics have been introduced, such as technological processes in microtechnology and training in CAM-systems. The aim is to respond more precisely and thoroughly to the increased demands in a market economy. There is also a laboratory "Automated design and technology of fine mechanical elements and devices". The company of German engineers (VDI) and FEANI has been given descriptions of the training in the specialty "PT" in TU-Gabrovo and developed qualification characteristics for the specialty. The disciplines are provided with textbooks and teaching aids [2, 3, 4, 5, 30]. In 1996 the technologies at the beginning of the XXI century and the training and development activity in the specialty "PT" of TU-Gabrovo were presented and discussed [6]. A study was conducted on which technologies should be developed and which of them should be introduced in the education of students. The training in the technological direction is divided into 8 thematic cycles and measures are proposed to increase the level of training on the path of integration with Europe.

In 1997 the topic of the development of information and communication technologies was reported and the tasks of PT and micro-technique were formulated [7]. The further development of more reliable and with many possibilities intelligent devices and means for different media is forecasted and an opinion is expressed on the ways in which these tasks can be solved. The desire to develop and apply new methods in training is realized with a project of multimedia training in the discipline TMEPT, developed at the EMK Institute at TU - Darmstadt in 3 stages, the results of which are presented in [8].

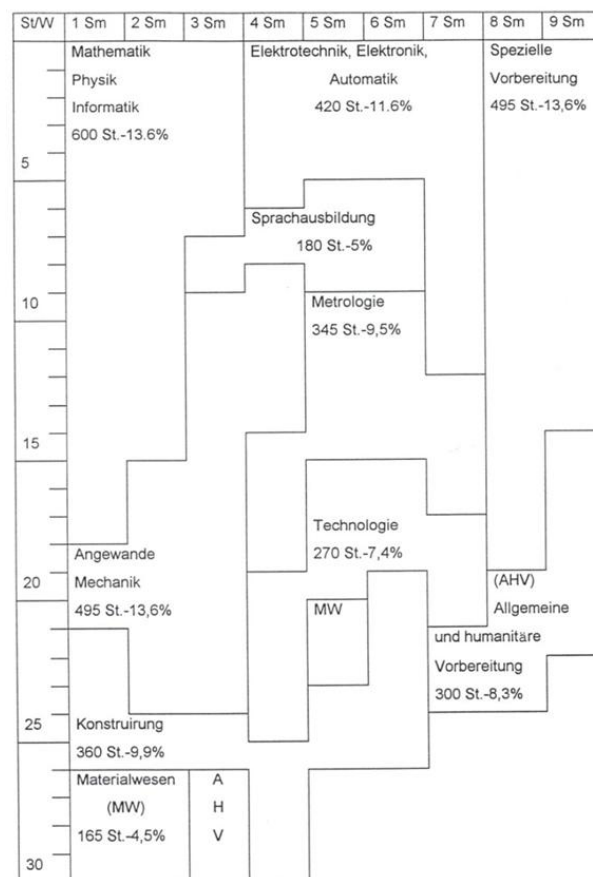


Fig. 1. Block-diagram of the curriculum for the specialty "PT" as of 1995

The goals and target groups of the project and the tasks solved with media-based training on the Internet by high-energy methods in micro-technique are indicated (Fig. 2). The final implementation of multimedia training in TMEPT in two languages (Bulgarian and German) was published in [9], presented abroad and announcing about 4000 entries in the WEB-page of the project [10]. The project has developed a fundamentally new automated approach and system that expands the possibility of training to a modern Hard / Software technology on the Internet by supplementing the place and time of implementation and has developed a methodology for user work. For distance learning 2000 is the IL-program. At the beginning of the XXI century (2001), due to necessity, the discipline Microsystems Technique (MST) was introduced, as well as the specialty "Power Supply and Electrical Equipment" at the Faculty of Electrical Engineering and Electronics (EE) and action was started to develop the specialty "Mechatronics". A curriculum on MST for special EE has been developed. The main goal is the development of MST in our country. To achieve it, the activities are indicated: staff training, modularity and standardization and development. The training is focused on 3 technological areas, profiling the modules of lectures - technologies for microstructuring and modification, materials and structures, system techniques. The problem is also discussed abroad [11]. The beginning of the century is also characterized by projects for technology centers. In order to

meet the requirements, a technological information center was established and implemented at the Technical University of Gabrovo, the activity of which was reported to [12]. The main point in its activity is the realization of technologies (mentioned as examples) and information services as a market application in certain 7 more important areas with expected benefits.

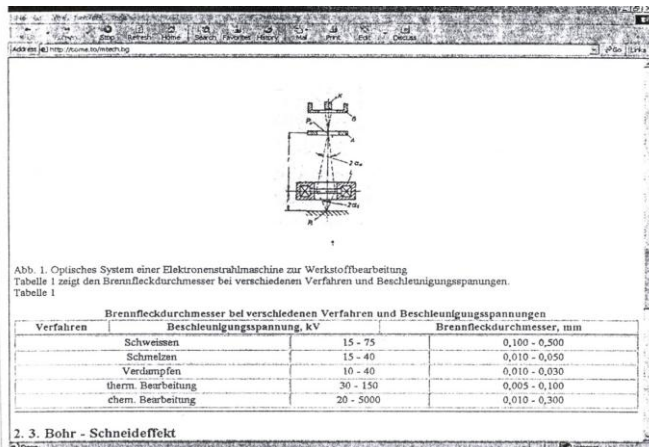


Fig. 2. Part of the lecture 'Electron beam processing' in German on the Internet

During the considered period of 30 years he was regularly involved in the development of new curricula and programs. From the beginning of 2001/2 the discipline TME is divided into two parts with a schedule of 90 hours of lectures and 30 hours of exercises. In 2003 a new program was prepared in TME and TMEPT, as well as in Production Equipment (PE), for 2 specialties in bachelor degree and began training in master degree with a program in the discipline TOD, which continues now. In the same year, a curriculum was developed in the discipline "Micro-technique" for the MEPT-specialty, and the MEPT department celebrates its 35th anniversary. In connection with this, an analysis was made of the state and trends in the development of leading technologies for micro- and nanotechnical products. New ideas for technologies in the field of biology, household and medical equipment, sensors for cars and smart homes, etc. are sought. Throughout the period there were programs for equations from Blagoevgrad, Lovech and other colleges, training in LTP in the specialty IT (2006), Logistics and UMP in distance learning (2005) and training of students in individual plans (for the Erasmus program, etc...). Under the new curriculum 2003/4, the disciplines SD and PE have been introduced with developed curricula from 2003 again for two specialties. From 2003/4, with new curricula, the discipline MST was renamed MT, and TMEPT became one semester with a workload of 45 + 30 hours. The tendency to reduce the load for all disciplines according to the requirements of the state and the university continues in the future and until now, when it is already 30 + 30 hours. In 2004 in connection with the accreditation programs were developed on "Ecological assembly and recycling of products" and "Waste treatment and recycling" for bachelor's degree and "Production of recyclable products" for master's degree who for various reasons have not entered the educational process, but it should be noted the introduction of the modular principle in them in the future. The new curricula from 2005 again require a program in the discipline TOD for masters degree, and for bachelor degree - TMEPT and MT. The pedagogical work is again connected with the research and an analysis of the state, application and trends in the development of the leading technologies in nanotechnology has been published [13]. The analysis is a continuation of the instructions above from 2003 and expresses an opinion on the development and forecast of

the leading nanotechnologies and their impact on the products until 2015. The development of the automated system "MICROSIS" for MT-components and selection of TP for their production as a habilitation work is implemented in the educational process [14, 28, 29] and provokes invitations to give lectures at NPUU KPI Kiev 2006 and SFU Krasnoyarsk, Siberia-Russia 2007. International contacts lead to the development of joint programs and work on projects published in [15, 16, 17]. Lectures were also given on disciplines from curricula at the University of Rēzekne, Latvia - 2 times and the University of Wilhelmshaven, Germany. In 2005 he was trained under the PUMP program in distance learning, and in 2006. A curriculum for LTP has also been developed. The integration between pedagogical and research work for the whole considered period of 30 years is visible. From 2007/8 the discipline Automated Waste Management Systems (ASWM) with a developed curriculum and project was introduced in the Master's Degree Program in Waste Management, and from 2008/9 - Technique and Technologies for Waste Treatment (TWT) for bachelors majoring in Waste Management. In 2006/7 a curriculum was prepared, and since 2008/9 the subject Metal-cutting machines and automatic machines (MMA) has been taught in Lovech. Curricula and lectures on "Programming of MM with CNC" and "Mechatronics" have been developed for TC-Lovech. Since 2009 a new discipline "Micro- and nanomechatronics" has been introduced for the open master's program in "Mechatronics". The same year the discipline "Mechanical and chemical technologies for purification" was developed for professional bachelors in preparatory training for masters, as well as "Technologies for purification of environmental components" for bachelors and masters outside the field of technical sciences. The same applies to the TPE discipline. In 2009/10 a new curriculum was introduced for a bachelor's degree in the specialty of vocational school and the discipline "Micro-technique", and in 2011 - new programs in PE, TMEPT, TTOO and MT for both specialties. The same year a new discipline "Programming and operation of MM with CNC" was developed for the specialty MUPT. The disciplines are provided with textbooks [18, 19]. In 2012/13 the specialty "Mechatronics" was introduced for bachelors, after 2009 there is one for masters, which requires the preparation of the disciplines "Nano-technique and Technology", "Micro-technique and Technology". New curricula have been developed for the basic discipline TMS, as well as a new discipline "Robotic modules and systems in production" (RMSP). The whole process of Mechatronics training was reported [20] at a round table of the UNITECH conference. More than 300 diploma projects have always been practice-oriented. The teaching materials are [21, 22, 23, 24, 25]. In 2015, in connection with the completion of the specialty of PTME, new plans, programs and disciplines were developed for different options for students entering the Master's degree in Mechatronics. In 2017-8, in accordance with the requirements of the business, the existing and introduced new programs and disciplines Advanced Technologies (AT), High Energy Technologies (HET), "Nano-technique and Technology" (NTT), were updated and introduced. An overview of all pedagogical developments by year is given in Table 1. The authenticity of the training can be recognized in the connections between the subjects - technological disciplines in the engineering specialties of TU-Gabrovo and most of all - in the profession of pedagogical engineer. Training that is evolving.

Table 1: Courses, programs and characteristics for the period of 30 years

Year	Bachelor's degree	Master's degree	Distance and electronic education, postgraduate qualification	TC Lovech and equating from colleges
1990-1994	TMEPT, Project			
1995	SD	TOD, course work	IL	
1996	APUP, TPT, TMEPT, Project			
1997	-		course for PC, Gabrovo	
1998	-		course for PC, Sevlievo „Инструмент“ Gabrovo	
1999	-		MT course for PC, Sevlievo	
2000	IL		IL	
2001	MST, TM		L in ВУНПЦ V.Tarnovo	
2002			L in ВУНПЦ V.Tarnovo KP postgraduate qualification	
2003	TMEPT, TME, MST, PE, MT, CD	TOD		
2004	EC, OPO	ПИОР		
2005	TMEPT, MT	TOD	IL, ПУМП	
2006	ЛТИ			MMA
2007	-	ASWM Project		MMA
2008	TWWT			
2009	“ТИКОС”, TPT	MNM, “ТИКОС”, TPT, MTT, NTT		МХТИ, MMA
2010	MT		course for PC, Фирма „Корона“	
2011	PE, TMEPT, TWWT и MT, Programming and operation of MM with CNC		Professionally training	
2012	MTT, NTT, TMS, RMSP			Programming and operation of MM with CNC and Mechatronics
2013	Double Degree Schmalkalden, Germany			
2014	-		Mechatronics - course for teachers	
2015	-	MNTT, TODM		
2016-2019	TMS, AT, HET	NTT		
2020	Attendance and distance learning			
Total	34	13	15	6

3. Conclusion

A model of training in mechanical engineering technology and derivative technological disciplines or one of the most important areas, which shapes the engineer, is shared. Its development in the last 30 years is given. The technological direction is divided into 8 thematic cycles, measures are proposed to increase the level of education on the path of integration with Europe and reflective teaching is introduced to form a distinctive personality. Multimedia learning is especially relevant now in the context of the Corona virus pandemic. The bibliography and curricula [26, 27] are available to those interested. The established innovative practice and the applied literature can be used in training and practice.

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Tanker inspection regime in correlation with maritime accident risks and management decisions

Luka Grbić ¹, Mirano Hess ²

University of Zadar, Department of Maritime studies, Croatia ¹

University of Rijeka, Faculty of Maritime Studies, Croatia ²

Abstract: The paper analyses and addresses various tanker ship survey regimes, determining a certain amount of overlapping between specific survey regimes. The results of the study indicate that there are inconsistencies in the frequency of surveys and over inspections of some ships. These uncoordinated surveys affect the costs as well as the mental and physical condition of the crew. The mentioned indicates the necessity of the overall tanker survey rationalization, having in mind that the rationalization must not have the negative impact on the safety of the ship. In this paper, the authors propose the implementation of the unified tanker survey model that would integrate components of all survey regimes. The comprehensive analysis of the risks arising from non compliance, oversights or absence of surveys, have resulted in setting up the optimal time needed to conduct surveys with respect to the technical, technological and economic specifications of the ship. The implementation of the unified survey would eliminate the negative effects found during present surveys and enhance the safety of the ship as well as the quality of the management.

Keywords: TANKER SURVEY, UNIFIED INSPECTION, VESSEL MAINTENANCE, SAFETY OF NAVIGATION, SURVEY COSTS

1. Introduction

The basic precondition for the successful operation of all on board systems is the implementation of adequate controls of ship systems. There are four basic groups of inspections for tankers: inspections performed by representatives of the flag state and port, inspections performed by representatives of recognized organizations, inspections performed by representatives of clubs and foundations, and inspections performed by company representatives. In addition to the above categories, it is necessary to mention special inspections that are characterized by different intensity and manner of inspections: inspections of shipyards and manufacturers of machinery / equipment, inspections of potential buyers of the ship and inspections of the crew.

The correctness of ship systems, as well as the integrity of the ship's construction are elements of the ship's operability that are ensured by adequate control and maintenance of the ship in accordance with the manufacturer's recommendations. For the purpose of successful operation of all systems on board, it is necessary to control them [1], [2]. For crude oil ships, there are 13 control regimes, divided into two groups:

External control:

1. port state control (PSC),
2. flag state control (FSC),
3. annual inspection of the recognized organization - ship register (Annual class survey),
4. examination of club representatives (P&I - Protecting and Indemnity),
5. inspection of the ship for charter (Vetting),
6. International Ship and Port Facility Security (ISPS) inspection,
7. inspection of safety management (ISM audit - International Safety Management),
8. inspection of working and living conditions on board (MLC audit - Maritime Labour Convention audit),
9. inspection of the Green award Foundation.

Internal control:

1. general inspection of the technical inspector of the ship,
2. internal ISPS audit,
3. internal audit of the safety management system (Internal ISM Audit),
4. internal Maritime Labour Convention audit.

In addition to the above regimes, there are certain inspections that are specific in intensity and manner of examination and in this paper are classified into a special group:

Special control:

1. inspections of shipyards and manufacturers of machinery/equipment,
2. inspections of potential buyers of the ship,

3. crew inspections.

This research has identified overlaps in inspections between certain regimes, increasing costs and psychophysical load of the ship's crew [1], [2]. This research focuses on purpose and effect of the inspection regimes, addressing improvement of the existing level of safety on tankers for crude oil and petroleum products.

2. Existing inspection regimes

Based on a detailed analysis of the records from five tankers and consultation with experts from the practice, all items from all 13 current inspection regimes were considered. Comparative analysis found that 1685 survey items can be reduced to 529 items, from which it can be seen that the overlaps in the regimes are 69%.

On all analysed ships in the four-year period, the number of inspection regimes that were performed within one month have been marked, which is shown in the following table.

Table 1: Intensities of monthly surveys over a four-year period.

Ship	Number of surveys in one month					
	1	2	3	4	5	Total
1 survey	4	8	7	6	6	31
2 surveys	13	5	4	10	10	42
3 surveys	0	3	3	1	1	8
4 surveys	1	2	1	0	3	7

Two inspections per month are the most common on all analysed ships. The reason for such a schedule of inspections is usually related to the time the ship stays in port. Since there are many regimes inspecting tankers, and the number of ports of call of tankers in one month is two to three times, during the stay of the ship in a favourable port, several regimes come under inspection. The term favourable port means a port that is well connected by roads, flights and other means of transportation. Since inspectors are not geographically distributed, which means that, for example, an inspector from Europe often goes to inspections in African and American ports, transport connections are extremely important.

The analysis revealed that there are a large number of cases in which the intensity of inspections is greater than two per month. These are inspections that have a negative effect on the psychophysical condition of the crew. The psychophysical condition of the crew is an element that needs to be constantly analysed for the safety of the ship, cargo and sea environment. In the same way as the number of inspection visits in one month is considered, one can also consider the number of months without inspection visits to the ship, which is shown in the table 2. The time mismatch between the inspection regimes results in the emergence of potentially dangerous time periods in the analysed four-year period. Time periods in which there are no inspections on ships can pose a potential hazard [3, 4, 5].

Table 2: Intensity of non-coverage of inspections in a four-year period.

Ship	Number of months without surveys					Total
	1	2	3	4	5	
2 months	6	1	0	0	3	10
3 months	2	3	3	3	1	12
4 months	1	4	4	2	3	17

In these terms, the inspection of ship maintenance, assessment of the quality of work, etc. is left exclusively to the ship's crews. Without the inspection of external stakeholders, the safety and technical correctness of the ship is potentially declining, which was the reason for the analysis of the current inspection regimes. From interviews with seafarers, inspectors in the ship owner's office, inspectors of recognized organizations and port authorities, and other maritime experts, it follows that the ideal schedule of visits to inspection regimes should be adjusted to ship crews [6, 7]. This should be done in such a way that at least one inspection of the external inspection regime is performed for the assumed average duration of the contract of the crew member on the tanker, i.e. 4 months. The reason for this is the psychological impact that inspections are left on crew members only [8, 9].

3. Optimisation of inspection regime

T will indicate the time in months between 2 unified inspections. In order to ensure that the consolidated inspection is accepted by the ship owner, care must be taken to ensure that the annual inspection price for the ship owner is lower than the existing one. Here, it will be assumed that the current price is USD 33,600, and that the cost of the unified review is USD 6,040 per survey. Therefore, the annual cost of a unified inspection is:

$$\frac{12}{T} \cdot 6040 \leq 33600 \quad (1)$$

and the conditional limitation is:

$$T \geq \frac{12 \cdot 6040}{33600} = 2.16 \quad (2)$$

The annual price of the unified inspection of shipping companies increases linearly with the number of inspections, or inversely according to the time between 2 inspections, which can be written as $66040 \cdot \frac{12}{T}$, which is illustrated in the following figure.

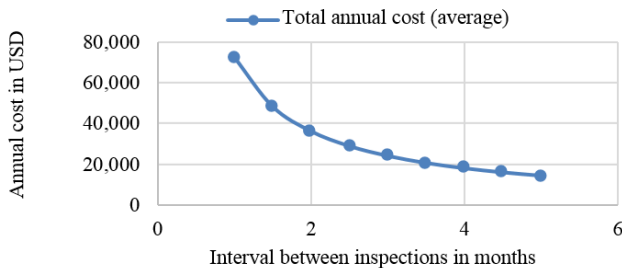


Fig.1 Inspection cost.

As mentioned earlier, there is a safety risk that there are no inspections in one crew contract. The requirement for each crew contract (which is estimated in this research to be a minimum of 4 months due to most of the companies whose officers were interviewed) to have at least one unified inspection, can be written by inequality:

$$T < 4 \quad (3)$$

The safety requirements to be met require that the annual number of items inspected be greater than the existing sum of items (1685). The unified inspection envisages 529 items. So it follows:

$$\frac{12}{T} \cdot 529 > 1685 \quad (4)$$

and condition:

$$T < \frac{12 \cdot 529}{1685} = 3.76 \quad (5)$$

which is shown in the following figure.

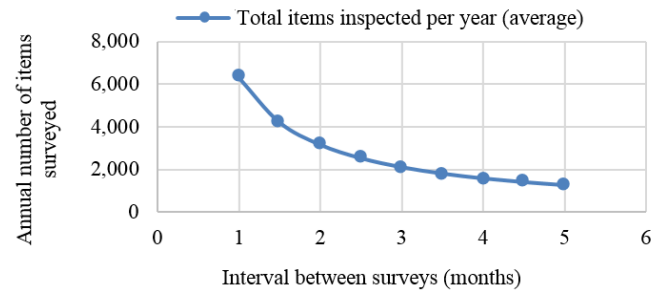


Fig.2 Total items inspected per year.

From the above model it can be concluded that from the point of view of cost for the ship owner and safety, the optimal interval between inspections is in the range of 2.16 to 3.76 months.

4. Inspections correlated with the risk of a maritime accident

Not one possible solution arises from the previous chapter, but several T between 2.16 and 3.76. The shorter the time between two inspections, the higher the annual price of the inspection, i.e. if the time between the two inspections is longer, the safety risk also increases. The general consensus of all stakeholders involved in the maritime enterprise in the process of preparing this paper is that the risk (probability) of an accident at one point depends on the elapsed time since the last inspection. The precise form of this dependence is dubious, but it is clear that it is growing. The simplest model is obtained by assuming that the dependence is linear (Figure 3), from which it follows that the total risk in the period between two inspections depends on the square of time T .

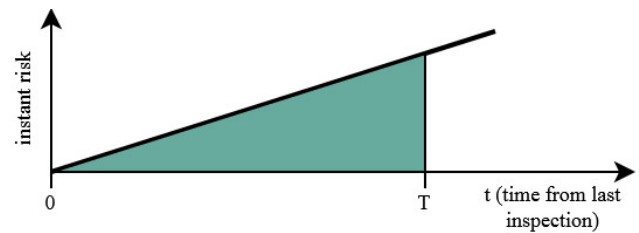


Fig.3 Linear dependence.

This can be expressed by an equation:

$$\int_0^T t \, dt = T^2 \quad (6)$$

Since the number of inspections per year is equal to $\frac{12}{T}$, it follows that the average risk depends on $\frac{12}{T}$. The expression $T^2 \cdot \frac{12}{T}$ depends linearly on T . Therefore, the longer the time T the higher the risk. The direction coefficient is a parameter that stands next to x . It shows how fast the direction is growing upwards. For a tangent to a curve, the direction coefficient is equal to the derivative of the function. Therefore, positive derivatives mean that the function increases, and negative derivatives mean that the function decreases (Figure 4 a).

The tangent $y = 2x - 1$ to the curve of a quadratic function at a point with parameter 1. The direction coefficient is equal to the derivative of the function at that point. The link of any two points on the curve of a quadratic function is located above the curve itself because it is a convex function. A positive curvature is the curvature that corresponds counterclockwise, and a negative curvature is a clockwise curvature. Concavity is another name for negative curvature, and convexity for positive curvature. The second derivative measures the curvature of the function. When the second derivative is positive then the function is positively curved, and when the second derivation is negative then the function is negatively curved (Figure 4 b).

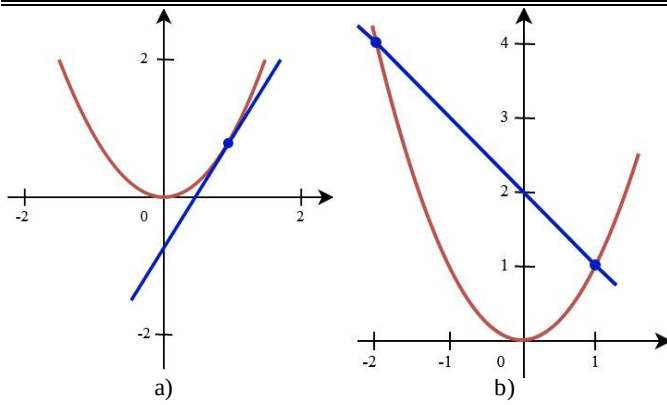


Fig.4 a) Relationship of 1st derivation with growth and decline of function. b) Relation of the 2nd derivative with the curvature of the function.

Another characterization of positive curvature is the fact that for such functions the coupling of any two points on the curve is above the curve of the function itself. For example, if the left point is determined by the parameter a and the value of the function $f(a)$, and the right point is determined by the parameter b of the value of the function $f(b)$, then the point at the midpoint of the coupling is at the height $\frac{f(a)+f(b)}{2}$ always above the point on the curve of the function $f\left(\frac{a+b}{2}\right)$. In other words:

$$f\left(\frac{a+b}{2}\right) \leq \frac{1}{2}(f(a) + f(b)) \quad (7)$$

One generalization of the above inequality, which is taken forward, is the Jensen inequality (Needham, 1993) which for the convex function f and its n parameters $x_1, \dots, x_n$ reads:

$$f\left(\frac{\sum_{k=1}^n x_k}{n}\right) \leq \frac{1}{n} \sum_{k=1}^n f(x_k) \quad (8)$$

A ship is a specific system on which, from the point of view of safety, many components operate in a complex way: in series and in parallel [10]. It can be assumed that the essential components of the system (human, organizational or technical) whose failure would potentially lead to accident are protected by the so-called parallel safety components: e.g. component condition indicators such as signal warnings, preventive component inspections, etc. External inspections have a special role to play here to ensure correct and reliable operation. Their ultimate goal is to eliminate system failures [11]. The concept of component life expectancy is well known in maintenance theory. The same is true for complex systems, where the probability of significant failure can be described as a function of the probability of the lifetime of the system.

It should be noted that the complex system is now observed without an external inspection system, in such a way that the system is certified by external inspection at time $t = 0$, and further in time the system operates without inspections. The probability that the system will fail in a time interval corresponds to the area under the curve. Denoting with p the function of the probability density of the lifetime of a complex system without conducting an inspection, and its cumulative function, which expresses the probability that the system will fail from the last inspection to the moment T , follows:

$$H(T) = \int_0^T p(t) dt \quad (9)$$

The life expectancy of a system on a large random sample would correspond very well to the time when half of the sampled systems would fail. The existing ship inspection system is the result of long experience and development within the maritime profession which has led to historically low levels of accident frequency. The already existing system has provided inspections in periods that are significantly below the expected lifetime and the maximum probability density of the lifetime of the ship's system in operation without the share of external inspections.

As Figure 4.b. suggests, it will be assumed that within a period of 12 months from the last inspection the life-cycle probability

density function increases. In other words, this means, starting from the assumption that in the period since the last inspection in 12 months, the probability density $p(t)$ that the accident will occur at time t , increases with increasing time parameter. The fact that the mentioned function p is increasing can be written with the help of derivation:

$$p'(t) > 0 \quad (10)$$

On the other hand, the so-called the basic theorem of integral calculus gives the relation between the functions $H'(t) = p(t)$, so for $t < 12$ in months:

$$H''(t) > 0 \quad (11)$$

Therefore, the probability that the system will fail from the last inspection until the moment within the next 12 months is a convex function to which the Jensen inequality can be applied, which for $n = 4$ reads:

$$H\left(\frac{t_1+t_2+t_3+t_4}{4}\right) \leq \frac{1}{4}(H(t_1) + H(t_2) + H(t_3) + H(t_4)) \quad (12)$$

If in expression $t_1 + t_2 + t_3 + t_4 = 12$ both sides of the inequality are multiplied by the number 4, the conclusion follows:

$$4H(3) \leq H(t_1) + H(t_2) + H(t_3) + H(t_4) \quad (13)$$

The preliminary result means that with the above assumptions, four ship inspections within 12 months would be optimally distributed at equal time intervals of 3 months.

5. Selecting the optimal inspection regime

The analysis of all parameters concluded that the optimal time to conduct a ship inspection is every three months. The stated intensity of inspections requires 4 inspections per year. From figure 5 it is possible to determine the time for the implementation of the unified inspection.

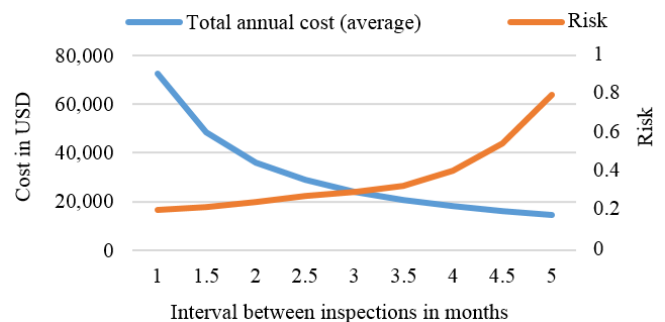


Fig.5 Price and risk compromise.

If the set conditions with the selected mode is observed, all the requirements are met:

- the average annual price is lower than the current annual level,
- the inspection time of the ship is shorter than the current one on an annual basis,
- crew members will be inspected at least once during their stay on board,
- the number of annual items for inspections will be higher than at present, which implies better safety of the ship and cargo.

Table 3 shows the relation of inspection costs of the current and unified inspection and the total hours spent in inspection.

Table 3: Savings through the unified inspection (USD).

Regime	Total annual inspection time (hours)	Total annual inspection cost (USD)	Price per hour of inspection
All current regimes	89	33600	378
Unified inspection	64	24162	378
Savings	25 28%	9438 28%	

The combined time savings is 25 hours per year. The time savings can also be viewed in terms of the time required to prepare for the inspection, which is also equivalent to the money savings. The savings are about USD 10,000 a year. For a ship that exists in a very competitive market, it is an exceptional savings.

The following table compares the unified inspection and the current regimes by inspection items. Inspection items are the most important segment in the unified inspection regime [12, 13]. Their number increases by 30% on yearly basis.

Table 4: Optimal number of items inspected.

No.	Segment	Total annual items inspected (all regimes)	Number of unified inspection items	Annual intensity	Total annual number of items inspected (unified inspection)
1	Ship certificates	95	21	4	84
2	Crew certificates	57	20	4	80
3	Lifesaving appliances	75	13	4	52
4	Fire safety	112	27	4	108
5	Navigation	234	56	4	224
6	Ship's procedures	192	55	4	220
7	Bridge publications	49	32	4	128
8	Ship's records	195	74	4	296
9	Mooring/anchoring	58	23	4	92
10	Structural condition – hull & deck	82	24	4	96
11	Structural condition – ballast & void spaces	20	12	4	48
12	Health & hygiene	92	26	4	104
13	Machinery space operations	149	50	4	200
14	Steering gear system	40	10	4	40
15	Environmental protection	64	24	4	96
16	Cargo worthiness, tanker	158	50	4	200
17	Cargo control room	13	12	4	48
	Total	1685	529		2116

Increasing inspection items will not negatively affect the psychophysical load of the crew because the timing of the inspection would be precisely defined. Situations that happen to current regimes that within a month a ship visits two or more regimes would be eliminated. Increasing the inspection items would positively affect safety.

6. Correlation between the degree of success of the unified inspection and value of ship on maritime market

The success of the unified ship inspection is directly related to its business value. Using the elements achieved by the proposed model, the correlation between the unified inspection and ship value could be described through the following items:

- elimination of overlaps in inspection items,
- increase in inspection items,
- reduced psychophysical load of the crew,
- reduced inspection costs,
- improved ship maintenance,
- increased safety on ships,
- extended life of the ship,
- facilitated operational planning of carriers,
- reduction of hull and machinery insurance premiums,
- reduced club insurance premium,
- easier planning of budget, service, procurement of spare parts and docking,
- more favourable and stable freight rates,
- greater business success and reputation of the ship owner.

All these elements increase the value of the ship in business.

7. Conclusion

Enhanced tanker inspection contributes to improved ship owner business. That is achieved by higher technical and technological safety of the ship through continuous inspections. Technological safety refers to all those components that contribute to better ship operations and are not technical components. Improved quality of

work of ship's crew when performing the most demanding trade operations is the most important component of the unified inspection.

The ship owner business is directly related to the way the ship is inspected. This research showed that optimal inspection interval, from the point of view of cost for the ship owner and safety, would be in the range of 2.16 to 3.76 months, that is 4 times a year.

The improvement of the owner's business can be observed from several aspects. The first aspect is savings on maintenance costs. Maintenance costs can be viewed as costs that are directly related to the costs of the intervention and the costs of the maintenance service. In addition, there are indirect maintenance costs, which include all costs incurred as a result of downtime. Another aspect of the improvement can be observed through better crew performance. A crew whose psychophysical load has been reduced meets the precondition for a smaller number of maritime accidents and omissions. According to statistics from the International Maritime Organization, 80% of maritime accidents are the result of human error. This fact should be greatly reduced by the proposed model.

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Development of combined feed technology based on secondary raw material resources

candidate of Technical Sciences Altynbayeva G.¹, candidate of Technical Sciences Kadnikova O.², candidate of Technical Sciences Aidarkhanov A.³, Baimukhanova J.⁴

Rudny Industrial Institute, 50 Let Oktyabrya Str. 38, Rudny, 111500, Republic of Kazakhstan (1, 2, 3),

Institute of High Technologies, Bogenbai batyr Str. 168, Almaty, 050012, Republic of Kazakhstan (4)

Email: altynbaeva_g@mail.ru, kadnikovaolga@mail.ru, aid_arman@mail.ru, jamilya_db@mail.ru

Abstract: Technological, technical and strategic solutions for the processing of feed with the use of substandard raw materials together with secondary raw materials of food production (waste of grain processing, flour-grinding, brewing industries, etc.) are presented: processing of compound feed with polysteam lactic acid sourdough based on whole-ground flour from waste processing of legumes.

Keywords: COMBINED FODDER, UNCONDITIONAL GRAIN, PRODUCTION WASTE, POLYSTAMM SOURDOUGH OF LACTIC ACID BACTERIA

1. Introduction

At the modern level of developed industry in the production of compound feeds great importance is attached to saving material resources, reducing their cost, and producing high quality compound feed. In Kazakhstan, in the production of compound feeds there is a problem of providing compound feed enterprises in sufficient quantities with high-quality raw materials, which make it possible to produce a variety of compound feeds balanced in nutrients in accordance with the physiological needs of farm animals and birds. Many branches of the food industry, when processing agricultural raw materials, generate waste, most of which are secondary raw materials [1].

Of all the variety of raw materials used in industrial technological processes [2-4], plant raw materials are currently a promising renewable resource that can be used as a substrate for growing microorganisms and producing sourdough. At the same time, not only agricultural crops can be used for bioconversion, but also plant wastes (husks, husks, bran), as well as by-products of the processing of agricultural raw materials (distillery stillage, molasses, refined syrup, oilcakes, waste from starch and sugar factories). In this case, it is possible to dispose of waste that pollutes the environment.

Renewable plant materials are of great interest for industrial biotechnology in feed production [5].

In the north of Kazakhstan, the main sources of renewable raw materials are cultivated grain crops. Being the largest grain state, Kazakhstan sows large areas of hectares with grain crops, of which 70% is allocated for wheat. In the southern regions of Kazakhstan, sunflowers, corn, soybeans, rapeseed, rice, sugar beets, many vegetables and fruits are grown. Kazakhstan has huge resources of plant raw materials, which especially contributes to the development of biotechnology. Due to the extreme prevalence and replenishment, vegetable carbohydrates can serve as excellent raw materials for a number of industries, including microbiological ones [6].

Since the northern region of Kazakhstan is located in the zone of risky farming, with the existing organization of agriculture, the harvest is 80% dependent on weather conditions [1]. The shortage of food resources, associated with significant fluctuations in the qualitative and quantitative indicators of the produced grain, leads to the need to accept and process grain that does not meet quality standards.

At the same time, the experience of grain processing enterprises testifies to a relatively low level of use of substandard wheat grain, other cereals and legumes for food purposes. It should be noted that the traditional approach to the processing of grain supplied to the enterprise consists in preliminary bringing its quality to the requirements of regulatory documents, followed by its direction for processing. However, bringing the quality of grain to meet the requirements of standards is not always technologically efficient and economically feasible, therefore, a significant part of substandard grain is directed to feed and technical purposes.

2. Results and discussion

The variety of types of plant raw materials that can be used for the production of combined feed dictates the need for a differentiated approach to solving the problem of its bioconversion, based on the chemical and physical properties of the raw material, its localization and economic prerequisites.

In connection with the current situation, the expansion of the fodder base, in particular, the use of non-traditional energy and protein sources, i.e. increasing the nutritional value of low-value feed raw materials and plant waste of various types, including substandard grain as a non-scarce waste of field cultivation.

Agricultural raw materials were selected for research, in particular substandard wheat grain and soybean waste. This choice is justified by the utilization of agricultural waste and the actual problems of feed protein in Kazakhstan.

Soybean crops in our country are small, but they are constantly expanding. Soybeans rank first in the world economy among legumes [7].

There are three main ways of processing low-value plant materials: physical, chemical and biological [8-10]. The latter method opens up unlimited possibilities for feed production.

In this way, a carbohydrate-protein feed is obtained based on low-value plant materials, which has the most important thing - high nutritional value [11]. In search of a more independent and cheaper way of obtaining carbohydrate-protein feed from substandard grain, it was proposed to use a specially developed starter sourdough based on soy flour and meal instead of enzyme preparations. Substandard grain is processed in a biological, that is, in a natural way with the help of special microorganisms contained in the leaven, a small amount of which is sufficient for processing a large amount of substandard grain. At the same time, the nutritional value of the grain is more than doubled. So 1 kilogram of unconventional grain treated with sourdough can be compared in nutritional value with 2 kilograms of food grain.

Substandard grain is a material that has a high carbohydrate content of 70% and a low protein content of 10-15%. In addition, pure grain is poorly eaten by livestock and has a relatively low digestibility of nutrients (Table 1).

Table 1: Chemical composition, digestibility and nutritional value of substandard grain

Indicators	Feed wheat
	Content, %
1	2
Dry matter	85,2
Protein	12,3
Fat	2,3
Fiber	4,4
Sugar	1,5
Cinder	2,4
Energy value	
Feed units / kg	1,16
MJ / kg	11,4
Content in 1 kg	

Digestible protein, g	108,0
Amino acids, g	
lysine	3,9
methionine + cystine	4,1
tryptophan	1,8
Macronutrients, g:	
1	2
calcium	1,9
phosphorus	3,0
sodium	0,1
Microelements, mg	
copper	3,2
iron	41,0
iodine	0,2

Because of poor degradability of fiber in the gastrointestinal tract and the low content of nutrients, animals are not able to consume large quantities of substandard grain. Diets saturated with substandard grains do not provide high animal productivity. The development of environmentally friendly biotechnological processes for the conversion of this type of raw material contributes to the production of valuable targeted feed [12].

For the effective destruction of the carbohydrate complex of substandard grain, a starter sourdough based on soy flour and soybean meal was used. The starter sourdough was prepared at a pH of 5.1-5.2 with the addition of a 0.5% lactose solution to activate lactic acid bacteria capable of destroying lactose. To a substrate consisting of 1 part of grinding (0.6 part of soy flour and 0.4 part of soybean meal) and 2 parts of water heated to a temperature of 90-100°C, a microbiological preparation was added at the rate of 0.1 g per 1 kg of substrate and 0.5% lactose solution at the rate of 100 g per 1 kg of substrate. The starter obtained in this way was left to ripen for 6 hours, and without lactose for 12 hours at room temperature. The seed obtained in this way was used when sowing substandard grain. For this, shredded wheat was placed in a 3000 ml chamber, moistened to a moisture content of 60%, and seed was added. Fermentation was carried out for 3 days (72 h) under anaerobic conditions at a temperature of 25°C with an initial pH of 5.1-5.2. After 36 hours at the end of the exponential phase of growth of microorganisms to activate the biosynthesis of enzymes, 0.5% lactose solution was added discretely to the substrate (at the rate of 100 g per 1 kg of raw material). The efficiency of destruction of the wheat complex was assessed by the accumulation of reducing substances in the fermentolysate (Table 2).

Table 2: Efficiency of the biodegradation process of substandard grain for the accumulation of reducing substances

Microbiological processing conditions	The content of reducing substances,%					
	time of microbiological treatment, h					
	12	24	36	48	60	72
Without adding lactose solution	2,09±0,10	3,10±0,06	4,03±0,08	5,60±0,20	7,19±0,11	8,4±0,08
With the addition of lactose solution after 36 hours of fermentation	2,09±0,10	3,10±0,06	5,03±0,06	6,40±0,09	9,10±0,01	9,40±0,09

After 72 hours of fermentation, 51% of the grain fiber was destroyed. The crude protein content was 12.8%, which is 4% more than in the native form of wheat grain. The content of reducing substances with the addition of lactose solution is 23.3% higher than without the addition of this component.

Thus, the treatment of substandard grain (wheat) with sourdough based on soy flour and meal reduces the fiber content by an average of 51%, increases the crude protein by 4%. Biodegradation of substandard grain is effective when a 0.5% lactose solution is added. The content of reducing substances in the product is 23.3% higher. The technical result of the research is to obtain a feed product rich in biologically active prebiotic, probiotic components.

The experimental data obtained determine the main directions of processing substandard wheat grain with microbiological starter sourdough based on soy flour and meal to obtain sugared bulky feed for further use as a feed product in animal husbandry. The results of the study served as the basis for the development of a technological scheme for obtaining a feed product using a starter sourdough based on soy flour and meal (Fig. 1).

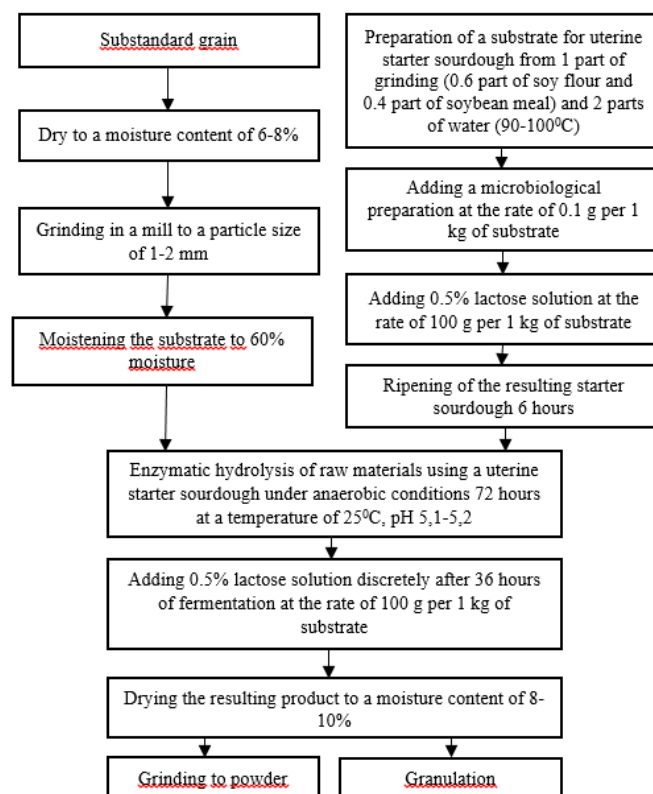


Fig. 1 Process flow diagram of a feed product by processing substandard grain using a starter sourdough based on soy flour and meal

3. Conclusion

The analysis of the literature showed that failure to comply with the conditions for harvesting and storing grain leads to an increase in the fiber content in cereals, a sharp decrease in their sugar content.

Protein deficiency is also a key issue for dairy farming.

The studies substantiated the possibility of using substandard grain as a raw material for obtaining feed of increased nutritional value and utilizing soybean processing waste in the leaven used in the technological cycle.

An important task was the search for active strains of microorganisms capable of processing cellulose, which is highly resistant to degradation by microflora.

The maximum yield of reducing substances was the main indicator of the efficiency of the process of destruction of wheat grain. Under the indicated conditions, the maximum protein content in fermentolysates was noted. Deep bio-fermentation was carried out at a mode: pH 5.2 and an ambient temperature of 25°C, which made it possible to consider these parameters as optimal.

It has been established that when processing a sourdough based on soy flour and meal of substandard wheat grain, it is possible to obtain protein-carbohydrate feed products for animal husbandry with a crude protein content of up to 12.8%. The starter used reduces the fiber content in substandard grains by an average of 51% and increases crude protein by 4%.

The targeted use of microorganisms contributes to the production of feed of stable quality. The technological effect of microorganisms is associated with the formation of specific biologically active components: organic acids, bacteriocins,

enzymes, vitamins, etc., which helps to improve the sanitary-microbiological, organoleptic characteristics of the finished product.

Enzymes such as protease, amylase, cellulase and their combinations hydrolyze proteins, starch, fiber and promote their better assimilation by the animal body, strengthen and normalize the digestion processes.

Thus, using microorganisms as producers of enzymes and fodder protein, the research tasks were solved – the production of protein mass and the utilization of crop waste, which can be sources of environmental pollution.

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Post-combustion CO₂ capture for coal power plants: a viable solution for decarbonization of the power industry?

Branimir Tramošljika, Paolo Blecich, Igor Bonefačić
University of Rijeka, Faculty of Engineering
Vukovarska 58, HR-51000 Rijeka, Croatia
paolo.blecich@riteh.hr

Abstract: This paper investigates the performance of post-combustion carbon capture and storage (PCCS) for pulverized coal-fired power plants. The PCCS units comprises CO₂ absorption by 30 wt% monoethanolamine (MEA) solution and CO₂ compression at 150 bar for permanent storage or enhanced oil recovery. The specific CO₂ emissions per unit of generated electricity is 733 kg_{CO2}/MWh in the reference power plant without PCCS while the power plant with integrated PCCS achieve specific emissions lower than 100 kg_{CO2}/MWh, assuming a carbon capture rate of 90%. However, PCCS technology needs substantial amounts of thermal energy for absorbent regeneration and electricity for carbon capture, CO₂ compression as well as for the operation of other parasitic electricity consumers. The PCCS energy requirements vastly affect the overall power plant performance. The reference coal-fired supercritical power plant (without PCCS) achieves a net efficiency of 45.1%. On the other hand, the PCCS integrated power plant achieves a net efficiency of 34.6%, a 10.5%-pts net efficiency loss over the reference scenario, when the PCCS specific energy demand is 3.5 MJ_{th}/kg_{CO2} for absorbent regeneration, 0.35 MJ_{el}/kg_{CO2} for CO₂ compression and 0.15 MJ_{el}/kg_{CO2} for carbon capture and cooling water pumps. The corresponding electricity output penalty caused by the PCCS unit is 352 kWh_{el}/kg_{CO2}. PCCS technology shows promising potential for decarbonization of the power industry, but further development is necessary to improve its reliability, cost-effectiveness and to diminish its impact on the power plant performance.

Keywords: POST-COMBUSTION CARBON CAPTURE, CO₂ EMISSIONS REDUCTION, COAL-FIRED POWER PLANT, ELECTRICITY OUTPUT PENALTY, NET EFFICIENCY LOSS,

1. Introduction

In 2019, the total global anthropogenic greenhouse gases (GHG) emissions reached 51.8 GtCO_{2eq} [1]. Figure 1 shows the GHG emissions by economic sectors in 2019. The largest sources of GHG involve: 1) fuel combustion (coal, natural gas and oil) for electricity and heat generation (25%), 2) fuel consumption for chemical, metallurgical and mineral transformation processes in various industries (21%) not associated with electricity or heat generation, 3) agriculture, forestry, deforestation, land use for crop cultivation and livestock (24%), 4) fuel consumption for road, rail, air and marine transport, where the majority of GHG is from the use of petroleum based fuels, mainly gasoline and diesel (14%), 5) fuel combustion in residential and commercial buildings, for heating and cooking, excluding electricity use (6%), 6) other energy related GHG emissions such as fuel extraction, refining, processing and transport, not directly associated with electricity or heat generation (10%). Energy related GHG emissions (fuel combustion & fuel fugitive emissions) represent 76% of the total global GHG emissions. Carbon dioxide (CO₂) is the largest contributor to GHG emissions since 90% of all energy-related emissions are originated from carbon oxidation. CO₂ alone represents two-thirds of the total GHG emission, or 35 Gt in 2019 [1]. The remaining one-third of the GHG emissions is due to: 1) methane (CH₄) emitted during fossil fuels extraction and production, and from agriculture, livestock and organic waste decay, 2) nitrous oxides (NO_x) generated from fossil fuel combustion, agricultural activities and waste management, 3) man-made gases (CFCs, HFCs, PFCs, SF₆) used in air-conditioning and refrigeration systems and for industrial processes.

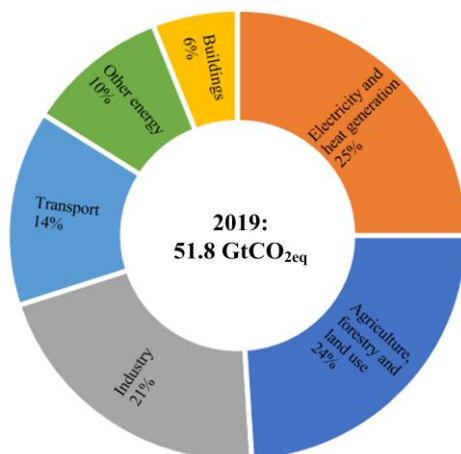


Fig. 1. Global GHG emissions by sectors in 2019

More than half of the total global GHG emissions are point sources GHG emissions originated from fuel combustion for electricity and heat generation, industry transformation processes and buildings. For example, electricity generations is still dominantly fossil-fuel generated, whereas coal, natural gas and oil supplied 63.5% of the worldwide electricity in 2019 [2]. Specifically, coal generated 9945 TWh (36.8%), natural gas 6376 TWh (23.6%) and oil 835 TWh (3.1%) to the worldwide electricity of 27005 TWh [1]. Fossil fuel electricity generation is encumbered by high GHG emissions into the atmosphere. The largest part of the GHG emissions is from CO₂, but NO_x, SO_x, soot and fly ash are also emitted from fossil fuel combustion. The specific CO₂ emission for electricity generations are in the range between 877 and 1130 kg/MWh for coal and between 422 and 548 kg/MWh for natural gas power plants. For comparison, lifecycle CO₂ emissions from renewable sources are estimated at 8–20 kg/MWh for wind power, 20–57 kg/MWh for geothermal power and 29–80 kg/MWh for solar PV [3].

The IEA sustainable development scenario [2] estimates that, for limiting the long-term global temperature increase within 1.5 °C, energy-related CO₂ emission should be reduced to 27 Gt by 2030 and further down to 15 Gt by 2050, from the present value of 35 Gt. On the other side, the business-as-usual scenario would result in a 20% increase of energy-related CO₂ emissions by 2035, which would lock the long-term temperature increase at 3.6 °C. In order to achieve this substantial CO₂ reduction, natural gas should replace coal as the principal source of combustion energy. However, natural gas could reduce CO₂ emissions by 50% while further reduction could be obtained by alternative gaseous fuels such as biogas, renewable and low-carbon hydrogen, synthetic natural gas and new technologies such as carbon capture, utilization and storage (CCS).

2. Carbon capture and storage technology

Nowadays, the CCS technology is shifting from pilot plant to large-scale demonstration projects, not only in the power generation sector but also in other sectors. The Global Status of CCS 2020 [4] reports 26 commercial CCS facilities currently in operation with a total carbon capture and storage capacity of 40.7 million tonnes of CO₂ per year (Mtpa). CCS units are being used in the following industries: natural gas processing (30.5 Mtpa), power generation (2.4 Mtpa), hydrogen production (2.2 Mtpa), fertilizer production (1.8 Mtpa), methanol and ethanol production (1.6 Mtpa), oil refining (1.4 Mtpa), iron and steel production (0.8 Mtpa). The two dominant carbon storage practices are enhanced oil recovery (30.7 Mtpa) and storage in dedicated geological formations (10 Mtpa). The estimated costs of CCS projects for fossil fuel power plants span over wide ranges of values, as reported in the relevant

literature [5-7]. The costs of CCS depend on the fuel type, the costs of labor, materials, operation and maintenance, the carbon capture technology, the costs of transport and storage, and the type of project (greenfield or retrofit). The levelized cost of electricity (LCOE) is between 61 and 87 US\$/MWh in power plants without CCS and between 94 and 163 US\$/MWh for power plants with CCS. The LCOE can be reduced to between 61 and 139 US\$/MWh if the captured CO₂ is sold to enhanced oil recovery projects instead of simply storing it in geological formations. The cost of captured CO₂ is between 33 and 58 US\$/t_{CO2}, while the cost of avoided CO₂ (including compression, transport, and storage) is between 44 and 86 US\$/t_{CO2} [5, 6]. Post-combustion CCS for combined cycle natural gas turbines (CCGT) or supercritical coal power plants with oxy-fuel combustion are predicted to operate with similar costs. Slightly higher costs were estimated for coal-based integrated gasification combined cycles (IGCC) with pre-combustion CCS [7]. The specific costs of CO₂ transport are between 2 and 15 US\$/t_{CO2}, depending on pipeline capacity, type (onshore or offshore), and length. The specific costs of CO₂ storage are estimated between 1 and 18 US\$/t_{CO2}, depending on the storage type (depleted oil/gas field, geological formation, or ocean storage) and the potential of using EOR credits. The worldwide CO₂ storage capacity is 400 billion tonnes of discovered capacities in oil and gas fields (depleted or for EOR projects) and 12,000 billion tonnes in potential (estimated) storage capacities in geological (saline) formations [4]. The CO₂ storage capacities are such that exceeds the global net-zero emission scenario. It is estimated that the CCS industry could be cost-effective with carbon prices between 40 and 80 US\$/t_{CO2} [4].

At the moment, two carbon capture demonstration projects are up and running in the power generation sector: The Boundary Dam power plant and the Petra Nova power plant [5]. The estimated annual carbon capture capacities are 1 Mtpa at the Boundary Dam power plant and 1.4 Mtpa at the Petra Nova power plant. Both are using amine-based post-combustion capture, applied on one coal-fired unit each, and the captured carbon is transported via pipelines for usage in enhanced oil recovery (EOR) projects. Usually, an extra two to three barrels of oil can be recovered for every tonne of CO₂ injected into the mature oil field. According to the IEA, EOR results in a net CO₂ emissions reduction, which means that the amount of permanently stored CO₂ is generally greater than the CO₂ emitted from the production and consumption of the recovered oil. Other studies found that CO₂ EOR projects generate negative emissions in the first part of the oil field lifecycle but positive emissions in the second part. In the Boundary Dam power plant, the non-CCS units generate electricity from lignite coal with a cost of 60 US\$/MWh while the CCS-refurbished unit operates at a cost of 120 US\$/MWh after selling CO₂ to an EOR field at a price of 25 US\$/tonne. The unit is able to absorb and capture CO₂ at a rate of 90% reducing emissions to 150 kg/MWh. The economic viability of both the Boundary Dam and the Petra Nova carbon capture facilities are affected by electricity and oil prices. Carbon capture for enhanced oil recovery projects tend to be unfeasible when crude oil prices are under 100 US\$/barrel. Three carbon capture technologies have been developed up to the stage of large-scale demonstration plants. These are pre-combustion carbon capture, oxyfuel combustion carbon capture and post-combustion carbon capture. Several more technologies exist at the prototype stage: chemical looping combustion, membrane separation, cryogenic separation, calcium looping. The CCS sector is envisioned to grow up to a total global capacity of 5600 Mtpa of CO₂ by 2050 [4].

3. Post-combustion carbon capture

In *precombustion capture*, the CO₂ is captured before combustion. The fossil fuel (coal, oil or gas) is fed to the gasifier along with oxygen from the air separation unit. The resulting syngas (a mixture of CO₂, CO, H₂O and H₂) is blown into the desulfurization and particle precipitation units and thereafter shifted to CO₂ and H₂ in the water-gas shift reactor ($\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$). CO₂ is separated in an absorption based stripper while H₂ is used for electricity generation in turbines and fuel cells or in

hydrogen powered vehicles. Alternatively, CO₂ and H₂ can be used for synthetic natural gas production using CO₂ methanation ($\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$). Pre-combustion carbon capture is generally used for integrated gasification combined cycle (IGCC) power plants. For example, the 580 MW Kemper power plant (Mississippi, USA) generates syngas from lignite coal and captures 65% of the CO₂ using the Selexol absorption process. The annual carbon capture capacity of the Kemper power plant is estimated at 3 Mtpa. In *oxyfuel combustion capture*, coal is burned in a mixture of oxygen and recycled flue gases because coal firing in pure oxygen from the air separation unit would result in excessive flame temperatures. The nitrogen-free flue gases from oxyfuel combustion consists primarily of CO₂ and H₂O. The carbon capture unit is installed in the flue gases treatment line, after the desulfurization and electrostatic precipitation.

Post-combustion carbon capture (PCC) is a mature technology that can be integrated in new power plants or existing power plants for retrofit or upgrade projects. CO₂ is separated from flue gases after the combustion process. The flue gases are dominated by high concentrations of nitrogen gas, which increases the energy requirements for carbon capture. Flue gases from natural gas combustion typically contain only 4% of CO₂ while flue gases from coal combustion contain between 12 and 15% of CO₂ per volume. *Absorption-based* carbon capture involves chemical or physical processes for the absorption of CO₂ into liquid solutions containing the absorbent. The absorbent is regenerated by increasing the solution temperature up to the point of breaking the CO₂-absorbent bond. Amine-based absorbents have been used for many years in the oil and gas processing industry and can remove up to 90% of the CO₂ from flue gases. After the desorber column, the CO₂ is filtered dehydrated and compressed for industrial utilization, enhanced oil recovery projects or permanent storage. *Adsorption-based* carbon capture involves chemical or physical processes for the adsorption of CO₂ using solid sorbents. Solid sorbents are less preferred than liquid absorbents as they achieve lower CO₂ capture rates although the energy demand for thermal regeneration is also reduced [8-9].

Figure 2 shows the typical amine absorption post-combustion carbon capture unit, installed in the flue gases treatment line after the DeNO_x unit, the electrostatic precipitators (EP) and the flue gases desulfurization (DeSO_x). After the first stage treatment, flue gases are directed into the absorber column, where the cold amine solution forms a rich solution by absorbing CO₂. The carbon-free flue gases are discharged into the atmosphere through the stack. The energy efficiency of the carbon capture unit is increased by installing a heat exchanger which preheats the rich amine solution and precools the lean amine solution. Inside the stripper (desorber, regenerator), the rich amine solution is separated into lean solution and wet CO₂. The heating demand necessary for amine regeneration is supplied to the reboiler by low-pressure steam extracted from the power plant steam cycle or steam generated in separate boiler. The lean amine solution is pumped back to the absorber through the heat exchanger. On the other side, wet CO₂ is having moisture removed in the overhead condenser. Dry CO₂ is compressed in a multi-stage compression process. Generally, intercooling between compression stages is used to lower the CO₂ temperature and decrease the CO₂ compression power duty. High-pressure CO₂ is fed into the pipeline and transported to permanent storage, enhanced oil recovery projects or industrial usage.

The biggest technical hurdle of the carbon capture technology is the high energy demand. Specifically, the heating duty for absorbent regeneration is between 2.0 and 5.0 MJ_{th}/kg_{CO2} [8], depending on the absorbent type, flue gases composition, the carbon capture technology and absorption rates. The cooling duty necessary for moisture separation, flue gases cooling, lean amine cooling, and CO₂ compression intercooling, is between 2.0 and 6.0 MJ_{th}/kg_{CO2} [8]. The auxiliary power duty for CO₂ compression is in the range between 0.30 and 0.40 MJ_{el}/kg_{CO2}, depending on the required pressure rise. Additional auxiliary power duty, for the operation of cooling water pumps, flue gases fans and solvent pumps, is between 0.07 and 0.21 MJ_{el}/kg_{CO2} [10].

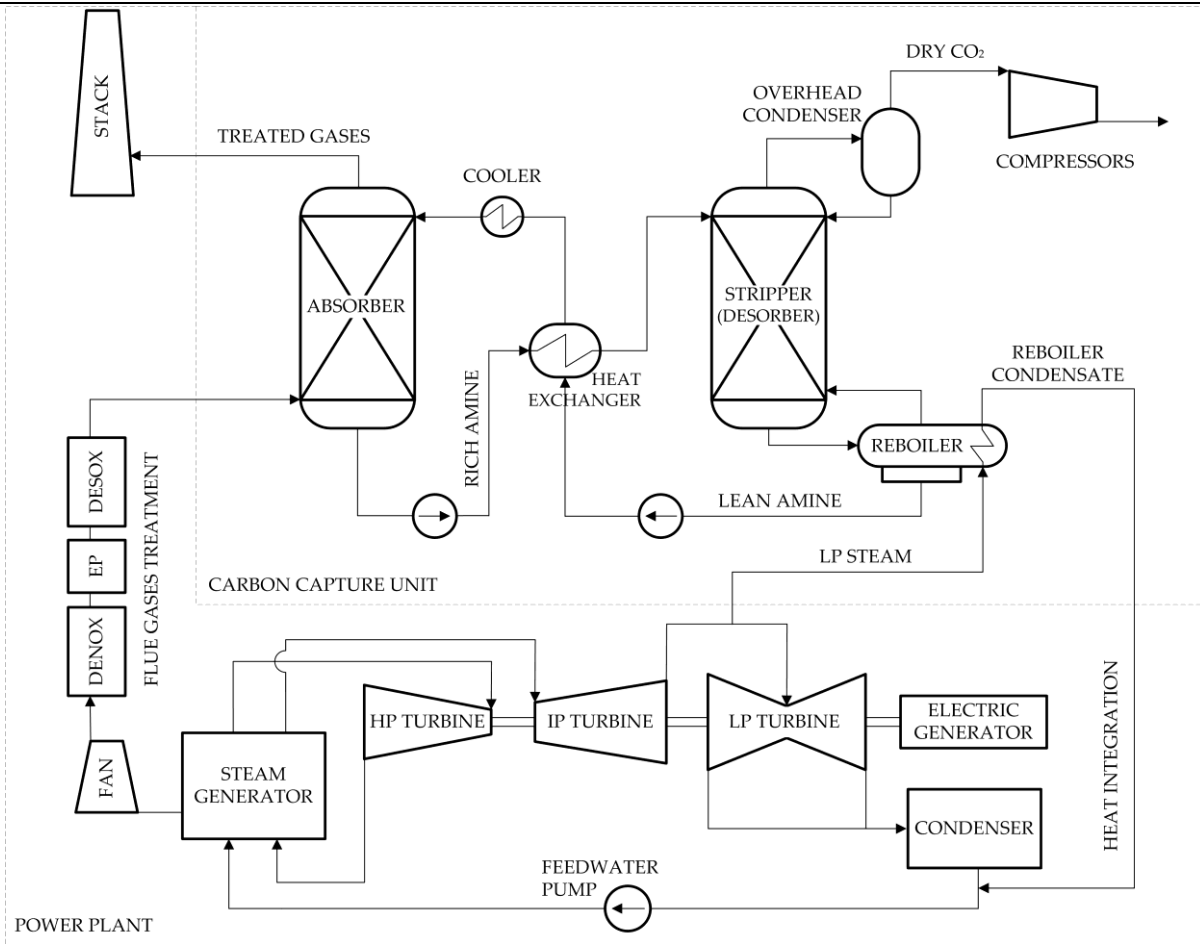


Fig. 2. Post-combustion carbon capture with amine absorption for a coal-fired power plant

4. Thermal efficiency and electricity output penalty

This section presents the methodology for assessing the impact of post-combustion carbon capture and storage (PCCS) technology on the performance of a coal-fired supercritical power plant. The reference power plant comprises a single-stage reheat and eight feedwater heaters (FWH). The electric generator is powered by one high pressure (HP) turbine, one intermediate pressure (IP) turbine and two double-flow low pressure (LP) turbines. Superheated steam enters the HP turbine with a temperature and pressure of 600 °C and 300 bar. Reheated steam enters the IP turbine with 610 °C and 60 bar. The steam generator efficiency is assumed $\eta_{sg} = 0.95$ while the turbine isentropic efficiencies are 0.90 for HP turbine, 0.94 for IP turbine, and 0.885 for LP turbines [11]. The net electric power of the reference power plant (without PCCS) is 500 MW. The gross electric power in the reference power plant ($\dot{P}_{el,gross,ref}$) is obtained adding auxiliary power ($\dot{P}_{el,aux,ref}$) to the net electric power.

$$\dot{P}_{el,gross,ref} = \dot{P}_{el,net,ref} + \dot{P}_{el,aux,ref} \quad (1)$$

In the present study, the auxiliary power is assumed 5% of the net electric capacity, i.e. 25 MW. The fuel heat input (LHV) necessary for the production of superheated and reheated steam is

$$\dot{Q}_{fuel} = \frac{\dot{m}_{steam} \Delta h_{superheat} + \dot{m}_{steam} (1 - \sum \varepsilon_i) \Delta h_{reheat}}{\eta_{sg}} \quad (2)$$

The power generated in the turbines is determined by the general expression taking into account the steam extractions, the isentropic enthalpy drops and the turbines isentropic efficiencies

$$\dot{P}_T = \dot{m}_{steam} [\sum (1 - \sum \varepsilon_i) \Delta h_i] \eta_T \quad (3)$$

The reference power plant net efficiency η_{gross}

$$\eta_{net,ref} = \frac{\dot{P}_{el,net,ref}}{\dot{Q}_{fuel}} = \frac{(\dot{P}_{T,HP} + \dot{P}_{T,IP} + \dot{P}_{T,LP}) \eta_{gm} - \dot{P}_{el,aux,ref}}{\dot{Q}_{fuel}} \quad (4)$$

The PCCS unit uses LP steam for amine absorbent regeneration through the reboiler. Therefore, the gross electric power of the PCCS-integrated power plant ($\dot{P}_{el,gross,PCCS}$) is less than the gross electric power of the reference power plant ($\dot{P}_{el,gross,ref}$) since low pressure steam is extracted from the IP/LP crossover pipe

$$\dot{P}_{el,gross,PCCS} = \dot{P}_{el,gross,ref} - \Delta \dot{P}_{el,PCCS} \quad (5)$$

The IP/LP steam extraction reduces the mass flow rate through the LP turbine. The corresponding power loss is the difference between the LP turbine power in the reference power plant and the LP turbine power in the PCCS power plant. Part of the turbine power loss is compensated by heat integration (HI) of reboiler condensate into the low-pressure feedwater preheating train. The net electric power of the PCCS integrated power plant is further reduced as result of the auxiliary power duty in the coal-fired power plant itself and the auxiliary power duty in the carbon capture unit

$$\dot{P}_{el,net,PCCS} = \dot{P}_{el,gross,PCCS} - \dot{P}_{el,aux,ref} - \dot{P}_{el,aux,PCCS} \quad (6)$$

The PCCS auxiliary power duty includes CO₂ compression power duty and the parasitic power duty for cooling water pumps, solvent pumps and flue gases fans. An eight-stage CO₂ compression process with the following parameters is assumed: compression efficiency 0.80, intercooling temperature 30 °C, final pressure 150 bar, carbon capture rate 0.90. The parasitic power duty in the PCCS unit is 0.15 MJ_{el}/kg_{CO2} [12]. The net efficiency penalty caused by PCCS is

$$\Delta \eta_{net} = \eta_{net,ref} - \eta_{net,PCCS} = \frac{\dot{P}_{el,net,ref} - \dot{P}_{el,net,PCCS}}{\dot{Q}_{fuel}} \quad (7)$$

The electricity output penalty (EOP) measures the performance loss caused by the PCCS unit. It is the ratio between the net electric power loss and the mass flow rate of captured and compressed CO₂

$$EOP = \frac{\dot{P}_{el,net,ref} - \dot{P}_{el,net,PCCS}}{\dot{m}_{CO_2}} \quad (8)$$

5. Results and discussion

The net electric power of the reference coal fired power plant is 500 MW. The total gross electric power output from the turbines is 535.7 MW: 166.1 MW from the HP turbine, 208.6 MW from the IP turbine and 161.0 MW from the LP turbine. The gross electric (generator) output is 525 MW, which against a gross fuel heat input of 1107.7 MW, yields a power plant gross efficiency of 47.39%. The auxiliary power duty is assumed at 25 MW, which return a net electric power output of 500 MW and a net efficiency of 45.14%. In the reference power plant, the total CO₂ emissions are 366.7 t/h while the specific CO₂ emissions per unit of generated electricity are 733.4 kg_{CO2}/MWh_{el}. The PCCS integrated power plant employs absorption-based carbon capture using 30 wt% monoethanolamine (MEA) solution. The fraction of CO₂ in flue gases is 21.2% on mass basis or 14.4% on volume basis. The CO₂ is absorbed by MEA aqueous solution, at a capture rate of 90% in the absorber column.

Table 1: Comparison between the reference power plant and the PCCS integrated power plant

Quantity		Reference	PCCS
Gross fuel heat input, MW _{th}		1107.7	1107.7
Steam generator net heat input, MW _{th}		1052.4	1052.4
Live steam mass flow rate, kg/s		389.4	389.4
Turbines gross power, MW _{el}		535.7	463.6
HP turbine power, MW _{el}		166.1	166.1
IP turbine power, MW _{el}		208.6	208.6
LP turbines power, MW _{el}		161.0	88.9
Total thermal discharge, MW _{th}		572.0	743.9
Steam generator heat losses, MW _{th}		55.3	55.3
Condenser thermal discharge, MW _{th}		516.7	267.9
PCCS thermal discharge, MW _{th}		-	420.8
Feedwater pump turbine power, MW _{el}		17.8	17.8
Power plant auxiliary power duty, MW _{el}		25.0	25.0
PCCS heating/cooling duty	heating, MW _{th}	-	320.9
	cooling, MW _{th}	-	420.8
PCCS auxiliary power duty	total, MW _{el}	-	45.8
	CO ₂ compression, MW _{el}	-	31.7
	cooling pumps, MW _{el}	-	13.9
Gross electric (generator) power, MW _{el}		525.0	454.3
Net electric (power plant) power, MW _{el}		500.0	383.5
Flue gases mass flow rate, t/h		1728.0	1398.0
CO ₂ capture, t/h		-	330.0
CO ₂ emissions, t/h		366.7	36.7
CO ₂ emissions, kg _{CO2} /MWh _{el}		733.4	73.4
Electricity output penalty, kWh _{el} /kg _{CO2}		-	352.9
Power plant gross efficiency, %		47.39	41.01
Power plant net efficiency, %		45.14	34.62
Net efficiency penalty, %-pts		-	10.52

The disadvantage of the MEA absorption process is the large energy consumption. The present study assumes that the specific heating duty of the capture process is 3.5 MJ_{th}/kg_{CO2}. This heating duty is supplied by LP steam from the IP/LP crossover pipe. Consequently, the LP turbines power is reduced to 88.9 MW, and the total turbine gross power is 463.6 MW. The gross electric power of the PCCS integrated power plant is 454.3 MW, which returns 41.01% of gross efficiency. However, fraction of the generated electric output is supplied to the PCCS unit, a total of 45.8 MW for auxiliary power, 31.7 MW for CO₂ compression and 13.9 MW for cooling pumps and other equipment. By combining the power plant internal duty and the PCCS unit auxiliary power duty, the total auxiliary power is 70.8 MW. The net electric power is 383.5 MW, a 23.3% reduction over the 500 MW in the reference power plant. The net efficiency is 34.62%, a net efficiency loss of 10.52%-pts over the reference value of 45.14%. The electricity output penalty per unit of captured CO₂ is 352.9 kWh_{el}/kg_{CO2}.

6. Conclusions

Absorption-based post-combustion carbon capture is a well-developed technology that can be successfully integrated into fossil fuel power plants. PCCS can reduce CO₂ emissions by up to 90%, but at the cost of efficiency and electricity penalties. The net electric power of the power plant without PCCS is 500 MW, while the PCCS integrated power plant achieves 383.5 MW. The reduction in the power output (116.5 MW) comprises the following components: LP turbine power output loss 70.9 MW (60.9%), CO₂ compression 31.7 MW (27.2%) and PCCS auxiliary consumers such as capture unit and cooling pumps 13.9 MW (11.9%). The net efficiency of the reference coal-fired power plant with supercritical steam cycle is 45.14%, whereas the net efficiency of the same coal-fired power plant with PCCS technology is 34.62%, an efficiency loss of 10.52%-pts. The resulting electricity output penalty per unit of captured and stored CO₂ is calculated at 352.9 kWh_{el}/kg_{CO2}. The disadvantages of the PCCS unit are the large energy requirements that cause substantial efficiency and electricity output losses. However, the advantage of the PCCS-integrated power plant is the reduction in CO₂ emissions, which can be up to 90% relatively to reference power plants without PCCS technology. In the present study, the reference power plant generates electricity with specific CO₂ emissions of 733.4 kg_{CO2}/MWh_{el}, whereas the PCCS integrated power plant operates at CO₂ emissions as low as 73.4 kg_{CO2}/MWh_{el}. Lifecycle CO₂ emissions, including upstream emissions from coal mining and transport, are higher, estimated at 100 kg_{CO2}/MWh_{el}. Future PCCS technology should achieve even higher carbon absorption rates but at lower electricity output penalties. Improved absorbent chemistry, advanced CO₂ capture process strategies and efficient CO₂ compression and storage are among the possible solutions. PCCS technology is ready for large-scale integration and inevitable for full decarbonization of the power industry.

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Analysis of the distribution of hydrogen and helium in the solar system during its formation.

Victor Tkachenko^{1,2*}, Georgy Tkachenko^{1*}

¹Kharkiv V.N. Karazin National University, 4, Svobody sq., 61022, Kharkiv, Ukraine

²National Science Center "Kharkov Institute of Physics and Technology", 1, Akademicheskaya St., Kharkov, 61108, Ukraine

E-mail: tkachenko@kipt.kharkov.ua, georgytkachenkoAspkaraz@gmail.com

Abstract: The modern composition of the Earth and other planetary systems is the result of the use of various different chemical elements. However, at the moment there is no unified theory describing the distribution of chemical elements during the formation of the solar system. Among the previously proposed theories and hypotheses, there are contradictions regarding the distribution of chemical elements in the solar system. Therefore, there is a need to create a physical model, which, on the basis of empirical data, represents the initial distribution of chemical elements from which the planets of the solar system were formed. In this work, it is proposed to analyze the initial system of the bladder and helium in the Solar System, starting from the moment of the formation of the protoplanetary disk. Assuming that at the moment of formation of the nebula, these elements were evenly distributed, their distribution was determined to date. Analyzing the percentage in the solar system, it was assumed that the differentiation of the ionized protoplanetary matter of the proto-carrier's magnetic field (magnetic separation of particles) caused the difference in the compositions of the outer planets. It is shown that according to the estimates given in the graphs, it receives 76-78% of hydrogen in the composition of the Earth, which in turn differs significantly from the data given in reference books or specialized literature - less than 17%. It has been suggested that the hydrogen content on Earth is incorrect.

Keywords: PROTOSPLAR SPACE, MAGNETIC SEPARATION, IONIZATION POTENTIAL, GRAVITATIONAL INSTABILITY

1. Introduction

At the moment, there are two main models for the formation of the solar system. The first model is the model of the formation of planets in the Solar System due to the accumulation of solids [1-3]. The second model is the model of large gravitational instabilities [4-9]. For 20 years, astrophysical research by the latest scientists to the discovery of gas and dust rings in protoplanetary stars. Gas-dust rings were predicted in models of large gravitational instabilities in protoplanetary disks [10-14]. As a result of cosmological observations of a solar-type star, the reliability of the hypothesis about the mutual formation of a solar-type star and its planetary system from one gas-dust protosolar fog was proved. Hence, these hypotheses follow [15-19]: the formation of planets began in a gas-dust protoplanetary disk; the law of rotation of the gas-dust protoplanetary disk is described (close) according to Kepler's law.

As the main process, it is associated with the formation of planetesimals in the dusty subdisk, which is determined by the boundaries, since the processes of unification of the formed solids are of a stochastic nature. From this we can conclude, that the model of solid-state accumulation of the formation of planets cannot explain the formation of gas-dust structures in the form of bright gas-dust ring structures separated by dark gaps. Analysis of the "bright" rings, which are observed in astrophysical studies of protoplanetary disks [20], shows bright rings, consisting of dust particles and gas. In the process of gravitational instability, the gas-dust medium passes from the space of the protoplanetary disk, which corresponds to the dark segments, and bright gas-dust rings with dark segments between them are formed in the bright rings. Then, in this process, the density of the gas-dust medium in the bright rings increases, and in the dark sections between them it decreases [11, 12]. It should be noted that during this process not only dust particles move, but also the gas component of the protoplanetary medium. With further development of gravitational stability, areas with increased density of the medium form gas-dust rings, and in the intervals between them, the gas-dust medium continues to decrease. In the process of evolution, protoplanetary rings are compressed, which may, due to gravitational instability [9], are distributed to gas and dust concentrations.

2. Ionization of protoplanetary disks

At the moment, there are two approaches to calculating the ionized structure of the protoplanetary disk [21]. The first approach allows one to calculate the degree of ionization of a medium in which recombination occurs on the surface of dust grains [22]. The second approach assumes that in the rarefied atmosphere of the

protoplanetary disk at its periphery, the main recombination occurs in the gas-dust phase [23]. Thanks to these approaches, it is possible to calculate the degree of ionization of the protoplanetary disk medium over the entire volume, as well as the ability to describe the process of plasma transition from the electron-ion state to the dust-ion state, where dust becomes the main charge carrier. Recently, a method has been put forward for ionizing protoplanetary disks by galactic cosmic rays, solar protons and supernova remnants [Ryuho Kataoka]. A strong influence on the formation of stars is created by strong ionization of the molecular cloud, due to the supernova remnant, changing the ambipolar diffusion time and the distribution of dead zones in the accretion disk [Fatuzzo et al., 2006]. According to the assumption, near the middle plane, where the ionization level is lowest, turbulence arises due to the magneto-rotational instability (Balbus and Hawley, 1991), which cannot exist due to the angular momentum. From this, the evolution of the protoplanetary disks themselves follows. dust grains and hence the origin of the planets (Sano et al., 2000, Okuzumi and Hirose, 2012). This means that many dead zones can exist in protoplanetary disks, given ionization from enhanced galactic cosmic rays or from enhanced solar protons [Turner and Drake (2009)].

Fred Hoyle suggested that the nebula's own magnetic field played a decisive role in the separation of the protoplanetary disk, consisting of ionized and neutral atoms of chemical elements. In his opinion, during the formation of the protoplanetary disk, the material ejected from the protosolar nebula should have moved, across the magnetic field lines (Fig. 1) [1].

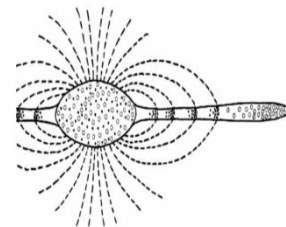


Fig. 1 Magnetic separation of charged particles during the formation of a protoplanetary disk. (black dots are ionized particles, light circles are neutral atoms)

Ionized, that is, charged, particles cannot cross magnetic lines of force, so they are captured by the magnetic field and stop in it, while neutral atoms freely pass through the magnetic field. The atoms of chemical elements differ in their ionization potential. Thus, if Hoyle's idea is correct, then during the formation of a protoplanetary disk, elements that are easily ionized should be captured by the magnetic field and stop in the circumsolar space,

while elements that are difficult to ionize go to more distant zones from the center. protoplanetary disk.

3. The content of hydrogen and helium in the planets of the solar system

Consider the distribution of hydrogen and helium in the solar system, since they are the main chemical elements that make up the sun's atmosphere. In addition, hydrogen and helium are also present on the planets of the solar system. Assuming that during the formation of the nebula, these elements were evenly distributed, we determine their distribution by now in time. Moreover, we believe that all chemical elements were in an ionized state, that is, they did not interact with each other (there was no collision between ions of chemical elements). To determine the content of hydrogen and helium, we use reference data [12]. Consider the gas giants of the solar system - Jupiter, Saturn, Uranus and Neptune. These four large planets are located in the outer solar system after the orbit of Mars. Jupiter and Saturn are much larger than Uranus and Neptune, and each pair of planets has a slightly different composition, but the main chemical elements are hydrogen and helium. In fig. 2, 3 show the distribution of hydrogen and helium depending on the distance to the Sun.

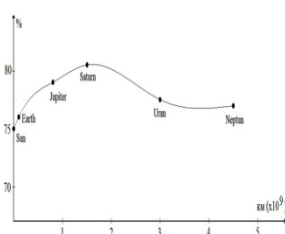


Fig.2 Distribution of hydrogen in the solar system.

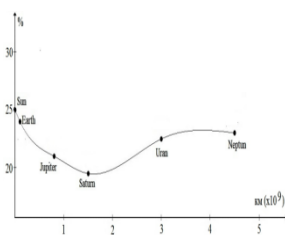


Fig.3 Distribution of helium in the solar system.

Analyzing the percentage of hydrogen in the solar system, we can make the assumption that the differentiation of ionized protoplanetary matter under the influence of the magnetic field of the proto-sun (magnetic separation of particles) causes a difference in the composition of the inner and outer planet. The inner terrestrial planets are enriched with metals, which are easily ionized and therefore "carried away" by the magnetic field of the protosun, while the outer giant planets consist mainly of easily ionized gases, such as hydrogen, helium, etc. methane. Thus, according to the calculations given in graphs 2 and 3, 76-78% of hydrogen atoms on Earth are expected to be obtained, which in turn differs significantly from the data given in reference books or special literature, which is less than 17%. The main confirmation of the incorrect estimate of the hydrogen content on Earth is the process of hydrogen evolution in nature [13, 18, 19].

4. Conclusions

The report describes the models of the formation of a protoplanetary disk in the solar system and the distribution of hydrogen and helium during its formation. The main methods of ionization of protoplanetary disks are also described. Compiled graphs of the distribution of hydrogen and helium in the solar system, relative to their distribution data on the gas planets of the solar system. It is

shown that according to the calculations given in charts 2 and 3, 76-78% of hydrogen atoms on Earth are expected to be obtained, which in turn differs significantly from the data given in reference books or special literature, which is less than 17%.

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Determination of energy loss and efficiency for the low power steam turbine and each of its segments

Mrzljak Vedran¹, Prpić-Oršić Jasna¹, Poljak Igor², Anđelić Nikola¹

¹Faculty of Engineering, University of Rijeka, Vukovarska 58, 51000 Rijeka, Croatia

²Department of maritime sciences, University of Zadar, Mihovila Pavlinovića 1, 23000 Zadar, Croatia

E-mail: vedran.mrzljak@riteh.hr, jasna.prpic-orsic@riteh.hr, ipoljak1@unizd.hr, nandelic@riteh.hr

Abstract: In this paper is performed energy analysis of the whole low power steam turbine as well as energy analysis of all the turbine segments. Analysis of the whole turbine resulted with energy loss of 14642.48 kW and energy efficiency of 75.01%, what is in range with similar comparable low power steam turbines. Energy analysis of the turbine segments presents a different conclusion than the energy analysis of the whole turbine. The fifth turbine segment (S5) has unacceptable high energy loss and unacceptable low energy efficiency (energy loss of 6785.93 kW and energy efficiency of 26.87%), so it should be repaired as soon as possible. This comparison show that proper energy analysis of turbine parts (segments) can detect the precise location of the problems during the turbine operation. Such analysis can be very helpful for the engineers because it allows detection not only the problematic components in the power plant, but also allows detection of the problematic parts of a component.

KEYWORDS: LOW POWER STEAM TURBINE, TURBINE SEGMENTS, ENERGY LOSS, ENERGY EFFICIENCY

1. Introduction

The most of electric power worldwide is produced by steam turbines. For the high power steam turbines, which are constituent parts of many various power plants, the dominant function is to transform high amount of mechanical energy into the electric energy [1-3]. Nowadays, mentioned high power steam turbines are composed of several cylinders, while each cylinder consists of many turbine stages [4, 5].

Low power steam turbines, in comparison to high power ones, are not so dominantly used worldwide. However, they have its functions in many systems, plants and processes. They can be found on ships for propulsion or for electric power production [6-8], in cogeneration power plants [9], in many processes for driving of various pumps or compressors [10, 11], in many industrial and complex power plants [12], etc.

In this paper is performed energy analysis of one selected low power steam turbine. Firstly was performed energy analysis of the whole turbine, after which is performed an energy analysis of all turbine segments (analyzed turbine has five steam extractions and six segments). The energy analysis of turbine segments can detect problems during operation in any turbine part (segment), while the analysis of the whole turbine cannot detect such problems.

2. Analyzed low power steam turbine description

The analyzed steam turbine operates as a part of steam power plant in an iron and steel facility [13]. The turbine has one cylinder which drives an electric generator, as presented in Fig. 1. Steam delivered to the turbine inlet (operating point 1, Fig. 1) is produced in a steam generator [14]. The turbine has five steam extractions – first two extractions (operating points 2 and 3, Fig. 1) delivers a certain steam mass flow rate to high pressure feed water heating system, one extraction (operating point 4, Fig. 1) delivers a certain steam mass flow rate to deaerator and last two extractions (operating points 5 and 6, Fig. 1) delivers a certain steam mass flow rate to low pressure condensate heating system. A steam mass flow rate, which remains after all extractions (operating point 7, Fig. 1) is delivered to the main condenser for condensation [15].

All seven operating points of the analyzed turbine represent places where steam operating parameters (steam pressure, temperature and mass flow rate) should be measured inside a power plant to get all the required data for the energy analysis. Measured data will define real (polytropic) steam expansion process inside the observed turbine.

Along with energy analysis of the whole observed turbine, in this paper will also be performed energy analysis of the turbine segments. Turbine segments are defined between operating points in Fig. 1 and marked from S1 to S6. Dividing of the turbine cylinder into the segments will allow calculation of energy efficiency and loss in each segment. In such way, detection of potential problems (high loss and low efficiency) inside each segment can be easily conducted.

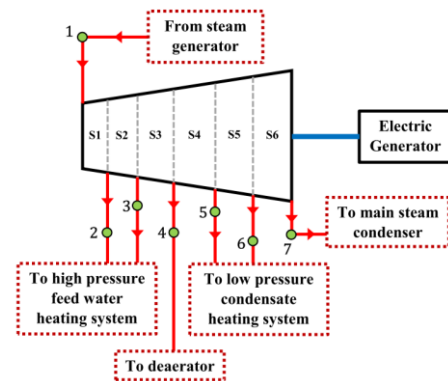


Fig. 1. Scheme of the observed steam turbine as well as operating points required for the energy analysis and markings of turbine segments (S1 – S6)

Measurement results in each operating point from Fig. 1 defines real (polytropic) steam expansion process presented in Fig. 2 with blue line and operating points 1-2-3-4-5-6-7. Operating points from Fig. 2 are defined in relation to markings from Fig. 1.

Energy analysis of any steam turbine or its segments, is based on the comparison of real (polytropic) and ideal (isentropic) steam expansion processes [16]. Ideal (isentropic) steam expansion process is the process between the same pressures and by using the same steam mass flow rates as in real (polytropic) expansion process, but assuming always the same steam specific entropy [17]. In Fig. 2, ideal (isentropic) steam expansion process for the whole analyzed turbine is marked with dashed red line and with operating point's 1-2is-3is-4is-5is-6is-7is. Steam operating parameters for the ideal expansion process are obtained mathematically. Dark red arrows in Fig. 2 represent steam extractions.

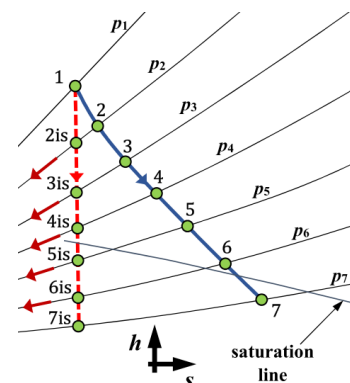


Fig. 2. Specific enthalpy-specific entropy (h-s) diagram of real (polytropic) and ideal (isentropic) steam expansion processes while observing the whole turbine

Energy analysis of the observed steam turbine segments cannot be performed in a same way and by using the same h - s diagram as for the whole turbine (Fig. 2).

Firstly, it should be stated that real (polytropic) steam expansion remains the same, with a same operating points, regardless of the fact if the whole turbine or turbine segments were observed, Fig. 3. When observing turbine segments, ideal (isentropic) expansion process begins at the inlet of each segment and lasts till reaching pressure at the segment outlet, Fig. 3. The main reason why for the turbine segments cannot be used h - s diagram of the whole turbine (Fig. 2) is fact that the isobars in that diagram are not parallel. The interval between two isobars increases during the increase in steam specific entropy. Therefore, for some turbine segments in Fig. 2 can be obtained that specific work in ideal expansion is lower than specific work in real expansion.

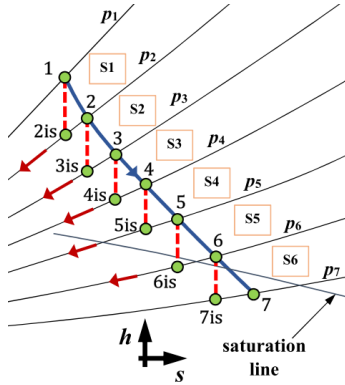


Fig. 3. Specific enthalpy-specific entropy (h - s) diagram of real (polytropic) and ideal (isentropic) steam expansion processes while observing the turbine segments

3. Energy analysis equations

3.1. Standard energy equations and balances valid for any component

In comparison to exergy analysis, which is based on the second law of thermodynamics and dependable on the conditions of the ambient in which component or system operates [18, 19], energy analysis is based on the first law of thermodynamics and is not dependable on the ambient conditions [20, 21]. Standard energy balance equation (disregarding potential and kinetic energies) is [22]:

$$\dot{Q}_{IN} - \dot{Q}_{OUT} + P_{IN} - P_{OUT} + \sum \dot{E}n_{IN} - \sum \dot{E}n_{OUT} = 0, \quad (1)$$

where $\dot{Q}$ is an energy transfer by heat, P is mechanical power, index IN denotes inlet (input) and index OUT denotes outlet (output). The last undefined variable from Eq. (1) is a total energy power of operating fluid flow ($\dot{E}n$) which can be defined according to [23] as:

$$\dot{E}n = \dot{m} \cdot h, \quad (2)$$

where $\dot{m}$ is operating fluid mass flow rate and h is operating fluid specific enthalpy. During standard operation (valid for any component or a system) fluid mass flow rate leakage did not occur, therefore the valid mass flow rate balance is [24]:

$$\sum \dot{m}_{IN} = \sum \dot{m}_{OUT}. \quad (3)$$

The standard energy efficiency equation is [25]:

$$\eta_{EN} = \frac{\text{CUMULATIVE ENERGY OUTLET (OUTPUT)}}{\text{CUMULATIVE ENERGY INLET (INPUT)}}. \quad (4)$$

Equations and balances presented in this sub-section are (and must be) fulfilled also in the energy analysis of the whole observed steam turbine and each turbine segment.

3.2. Energy analysis equations of observed low power steam turbine and its segments

Energy analysis of the whole turbine is based on the steam expansion processes presented in Fig. 2, while the energy analysis of the turbine segments is based on the steam expansion processes presented in Fig. 3. For the whole turbine energy analysis equations are presented independently, while for the turbine segments energy analysis equations are presented in Table 1.

Energy analysis of the whole turbine (WT)

- Real (polytropic) power:

$$P_{RE,WT} = \dot{m}_1 \cdot (h_1 - h_2) + (\dot{m}_1 - \dot{m}_2) \cdot (h_2 - h_3) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3) \cdot (h_3 - h_4) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4) \cdot (h_4 - h_5) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5) \cdot (h_5 - h_6) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5 - \dot{m}_6) \cdot (h_6 - h_7). \quad (5)$$

- Ideal (isentropic) power:

$$P_{ID,WT} = \dot{m}_1 \cdot (h_1 - h_{2is}) + (\dot{m}_1 - \dot{m}_2) \cdot (h_{2is} - h_{3is}) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3) \cdot (h_{3is} - h_{4is}) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4) \cdot (h_{4is} - h_{5is}) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5) \cdot (h_{5is} - h_{6is}) + (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5 - \dot{m}_6) \cdot (h_{6is} - h_{7is}). \quad (6)$$

- Energy loss:

$$\dot{E}n_{L,WT} = P_{ID,WT} - P_{RE,WT}. \quad (7)$$

- Energy efficiency:

$$\eta_{EN,WT} = \frac{P_{RE,WT}}{P_{ID,WT}}. \quad (8)$$

Energy analysis of the turbine segments

Table 1. Energy analysis equations of the turbine segments

SEG.	Real (polytropic) power	Eq.	Ideal (isentropic) power	Eq.
S1	$P_{RE,S1} = \dot{m}_1 \cdot (h_1 - h_2)$	(9)	$P_{ID,S1} = \dot{m}_1 \cdot (h_1 - h_{2is})$	(15)
S2	$P_{RE,S2} = (\dot{m}_1 - \dot{m}_2) \cdot (h_2 - h_3)$	(10)	$P_{ID,S2} = (\dot{m}_1 - \dot{m}_2) \cdot (h_2 - h_{3is})$	(16)
S3	$P_{RE,S3} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3) \cdot (h_3 - h_4)$	(11)	$P_{ID,S3} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3) \cdot (h_3 - h_{4is})$	(17)
S4	$P_{RE,S4} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4) \cdot (h_4 - h_5)$	(12)	$P_{ID,S4} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4) \cdot (h_4 - h_{5is})$	(18)
S5	$P_{RE,S5} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5) \cdot (h_5 - h_6)$	(13)	$P_{ID,S5} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5) \cdot (h_5 - h_{6is})$	(19)
S6	$P_{RE,S6} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5 - \dot{m}_6) \cdot (h_6 - h_7)$	(14)	$P_{ID,S6} = (\dot{m}_1 - \dot{m}_2 - \dot{m}_3 - \dot{m}_4 - \dot{m}_5 - \dot{m}_6) \cdot (h_6 - h_{7is})$	(20)
SEG.	Energy loss	Eq.	Energy efficiency	Eq.
S1	$\dot{E}n_{L,S1} = P_{ID,S1} - P_{RE,S1}$	(21)	$\eta_{EN,S1} = \frac{P_{RE,S1}}{P_{ID,S1}}$	(27)
S2	$\dot{E}n_{L,S2} = P_{ID,S2} - P_{RE,S2}$	(22)	$\eta_{EN,S2} = \frac{P_{RE,S2}}{P_{ID,S2}}$	(28)
S3	$\dot{E}n_{L,S3} = P_{ID,S3} - P_{RE,S3}$	(23)	$\eta_{EN,S3} = \frac{P_{RE,S3}}{P_{ID,S3}}$	(29)
S4	$\dot{E}n_{L,S4} = P_{ID,S4} - P_{RE,S4}$	(24)	$\eta_{EN,S4} = \frac{P_{RE,S4}}{P_{ID,S4}}$	(30)
S5	$\dot{E}n_{L,S5} = P_{ID,S5} - P_{RE,S5}$	(25)	$\eta_{EN,S5} = \frac{P_{RE,S5}}{P_{ID,S5}}$	(31)
S6	$\dot{E}n_{L,S6} = P_{ID,S6} - P_{RE,S6}$	(26)	$\eta_{EN,S6} = \frac{P_{RE,S6}}{P_{ID,S6}}$	(32)

4. Steam operating parameters for the analysis

In each operating point from Fig. 1 required steam operating parameters for real expansion process are found in [13] and presented in Table 2. Steam specific enthalpy and steam specific entropy are calculated from known steam temperature and pressure in each operating point (Fig. 1) by using NIST-REFPROP 9.0 software [26].

Steam operating parameters for ideal (isentropic) steam expansion process, according to Fig. 2, required in the energy analysis of the whole steam turbine, are presented in Table 3. In the energy analysis of turbine segments, according to Fig. 3, steam

specific enthalpies in each required operating point for the ideal (isentropic) steam expansion process are presented in Table 4.

Table 2. Steam operating parameters of the real (polytropic) steam expansion process

O.P.*	Temperature (°C)	Pressure (kPa)	Mass flow rate (kg/s)	Specific enthalpy (kJ/kg)	Specific entropy (kJ/kg·K)
1	532.00	8800	51.97	3469.6	6.7742
2	356.40	2363	2.27	3144.5	6.8952
3	304.70	1501	3.19	3048.6	6.9376
4	244.10	887	2.77	2934.4	6.9631
5	125.60	236	3.13	2714.0	7.0721
6	85.70	59	2.78	2652.6	7.5380
7	52.55	14	37.83	2524.5	7.8123

* O.P. = Operating Point (according to Fig. 1)

Table 3. Steam operating parameters of the ideal (isentropic) steam expansion process for the whole turbine (Fig. 2)

O.P.*	Pressure (kPa)	Mass flow rate (kg/s)	Specific entropy-isentropic (kJ/kg·K)	Specific enthalpy-isentropic (kJ/kg)
1	8800	51.97	6.7742	3469.6
2is	2363	2.27	6.7742	3070.3
3is	1501	3.19	6.7742	2957.5
4is	887	2.77	6.7742	2840.7
5is	236	3.13	6.7742	2595.2
6is	59	2.78	6.7742	2378.6
7is	14	37.83	6.7742	2186.4

* O.P. = Operating point (according to Fig. 2)

Table 4. Steam operating parameters of the ideal (isentropic) steam expansion process for the turbine segments (Fig. 3)

O.P.*	Pressure (kPa)	Mass flow rate (kg/s)	Specific entropy-isentropic (kJ/kg·K)	Specific enthalpy-isentropic (kJ/kg)
1	8800	51.97	6.7742	3469.6
2is	2363	2.27	6.7742	3070.3
3is	1501	3.19	6.8952	3024.3
4is	887	2.77	6.9376	2921.3
5is	236	3.13	6.9631	2670.6
6is	59	2.78	7.0721	2485.5
7is	14	37.83	7.5380	2435.2

* O.P. = Operating point (according to Fig. 3)

5. Results and discussion

Energy analysis of the whole observed low power steam turbine resulted with turbine real (polytropic) power equal to 43952.89 kW and ideal (isentropic) power equal to 58595.37 kW, Fig. 4. Energy loss of the whole turbine is equal to 14642.48 kW. Energy efficiency of the whole analyzed turbine is 75.01%. Such energy efficiency of the whole turbine is in range with other similar low power steam turbines from the literature [27]. Therefore, from the energy analysis of the whole observed turbine can be concluded that energy loss and energy efficiency are in range with other comparable low power steam turbines and that there is no obvious problems in operation.

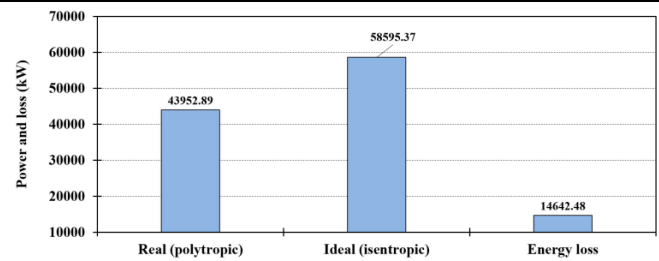


Fig. 4. Real (polytropic) and ideal (isentropic) power as well as energy loss of the whole analyzed turbine

Real (polytropic) and ideal (isentropic) power for each segment of the observed steam turbine are presented in Fig. 5. Analysis of obtained results for each segment leads to conclusion that the highest power (regardless if it is ideal or real) is developed in the first turbine segment (S1). Also, in S1 can be expected relatively high energy loss due to the highest steam pressure and temperature (much higher in comparison to other turbine segments). Segments two, three and four (S2, S3 and S4) will have low energy losses, because the difference between ideal and real power is small. For the last turbine segment (S6) is expected that the energy loss will be high, because only that segment (in comparison to all the others) operates with wet steam, Fig. 2 and Fig. 3. When observing fifth turbine segment (S5) it can be seen the highest difference between ideal and real power (in comparison to all the other turbine segments), Fig. 5. As S5 operates with superheated steam which did not consist of water droplets, the only reason for such operation of S5 can be found in some problems, the occurrence of the unexpected additional losses, degradation of turbine blades, etc.

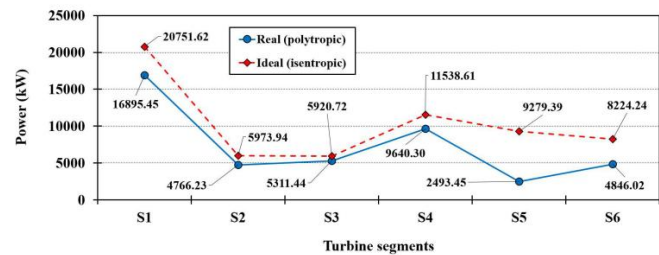


Fig. 5. Real (polytropic) and ideal (isentropic) power of the turbine segments

As mentioned before, the first segment of the observed steam turbine (S1) has high energy loss due to high steam pressure and temperature, Fig. 6. Slightly lower energy loss than in S1 can be observed in the last turbine segment (S6) due to operation with wet steam. Segments two, three and four (S2, S3 and S4) have low energy loss. The highest energy loss of all segments from the observed turbine can be seen in the fifth segment (S5), which can be explained only by some evident problems in that segment operation.

The energy efficiency of the first four turbine segments is reasonably high (around 80% or higher). The last turbine segment (S6) has an energy efficiency equal to 58.92%, what is also expected. Fifth turbine segment (S5) has an energy efficiency equal to 26.87%, what can be explained only by evident problems in operation.

Finally, it can be concluded that energy analysis of the turbine segments gives the proper presentation of turbine parts operation and can detect segments in which occur unexpected losses (as in the case of the analyzed turbine). Energy analysis of the whole turbine cannot detect such details.

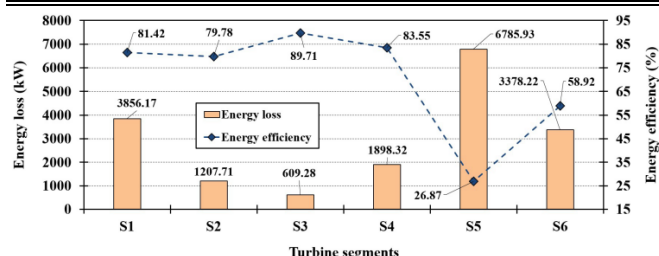


Fig. 6. Energy loss and energy efficiency of the turbine segments

Further research of the observed steam turbine and its segments will be performed by the application of many artificial intelligence methods and processes [28-31]. It can be expected that all of the further analyzes will result with a same conclusion that the fifth turbine segment (S5) should be repaired as soon as possible.

6. Conclusions

In this paper is performed analysis of energy loss and energy efficiency (energy analysis) of low power steam turbine which operates in an iron and steel facility. The energy analysis is firstly performed for the whole turbine, after which follows the analysis for all turbine segments. The main conclusions are:

- Energy analysis of the whole turbine resulted with energy loss equal to 14642.48 kW and with energy efficiency of 75.01%. Calculated energy loss and efficiency of the whole turbine did not show any potential problem in operation – such energy efficiency and loss are in the range with other comparable low power steam turbines.
- Energy analysis of turbine segments resulted with a fact that the fifth turbine segment (S5) has unacceptable high energy loss and unacceptable low energy efficiency (energy loss of 6785.93 kW and energy efficiency of 26.87%). Therefore, fifth turbine segment (S5) should be repaired as soon as possible.
- Presented analysis can be very helpful for the engineers in exploitation because it allows detection not only the problematic components in the power plant, but also allows detection of problematic parts of the components.

7. Acknowledgment

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Influence of the coefficient of shape of welding over strength of internal structural junctions of geocells

Konstrantin Chukalov

Department Mechanical equipment and technologies, Technical university Sofia, branch Plovdiv
chukalov@tu-plovdiv.bg

Abstract. Geocells are innovation products with wide application in practice. Engineering usage of them depends mainly on their mechanical properties. In this article will be analyzed the influence of the coefficient of shape of welding over internal structural junctions of geocells according EN ISO 13426-1:2019, method B.

1 Introduction

Geocells are structure of welded strips from HDPE (Fig.1). As compared to the planar form, the three-dimensional 'Geocell' is comparatively new invention in soil-reinforcement [1]. They take place of many infrastructure projects like construction of highways, rail roads, constructions of erosion control, construction of canals and fundaments. Their popularity, product range and applications continue growing due to the associated significant technical, economical and environmental advantages [1].



Fig.1 Geocells

2 Characteristics and application of geocells

Engineering characteristics may be separated to following groups: geometrical like welding distance, length of strips, cover area, type of perforation thickness of strips etc, physicochemical like density, coefficient of friction, oxidation time, UV stability and mechanical-tensile strength of strip and tensile strength of welding. The standardized applications are reinforcement, drainage, arming, separation. [3]. Wide application of geocells define individual approach according function, application, loading, desired cover area and many others factors. Analyze of specifications of some world producers shows that the main quality sign that distinguish the products is the average thickness of strips. The most common average thicknesses are 1.3 mm and 1.45 mm. Geocells are manufactured using ultrasonic welding technology. The width of welding is constant, because it depends only on tool of welding (horn). The most common width of welding is 10 mm. The Penetration depth is the amount of the both thicknesses of strips, therefore the shape of welding vary only when the average thickness of strips is changed. (fig) 2. [4].

The most common published by producers mechanical properties are

- Tensile strength of strips according ISO 10 319.
- Tensile strength of internal structural junctions according EN ISO 13 4261:2019.

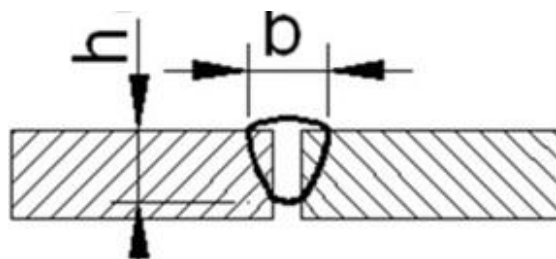


Fig. 2. Geometrical characteristics of welding, b -width of welding, h -penetration depth of welding

3. Testing

The testing are performed on calibrated universal two columns tensile testing machine KQL-5 kN (fig.3). The jaws of the testing machine are suitable for polymers, the width of jaws is compliant to the width of samples, the height of the machine is suitable to elongation of samples, the inside surfaces of jaws are knurled for better contacting. All testing requirements of the standard are met.



Fig..3 KQL-5 kN.

The testing include 10 samples with average thicknesses 1.45 mm, 1.3 mm and 1.15 mm from one batch. The chosen mechanical testing is strength of internal structural junctions according EN ISO 13426-1:2020, method B. The tested samples are from HDPE, width 100 mm, bilateral tolerance 3 mm, tolerance of average thickness till 5%. The location of sample and principle scheme is shown in fig 4.

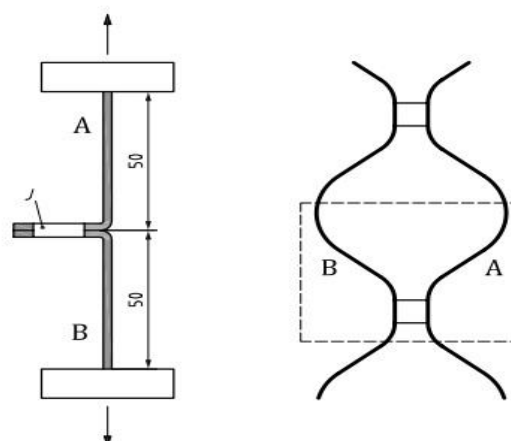


Fig. 4. Location of sample and principle scheme according EN ISO 13426-1:2020, method. [5].

For convenience only the maximum applied force will be recorded, the recorded dimension is kN, according the standard.

Average thickness- δ -1.45 mm

1.22	1.25	1.27	1.24	1.23
1.25	1.25	1.24	1.23	1.22

Average thickness- δ -1.3 mm

1.21	1.19	1.2	1.24	1.21
1.23	1.24	1.18	1.17	1.2

Average thickness- δ -1.15 mm

1.03	1.0	1.05	1.03	1.01
1.06	1.06	1.1	1.04	1.03

4. Statistic treatment of the recorded data

Maximum value	1.27 kN
Minimal value	1.22 kN
Dispersion	0.05 kN
Average value	1.24 kN

Average thickness- δ -1.45 mm

Maximum value	1.24 kN
Minimum value	1.17 kN
Dispersion	0.07 kN
Average value	1.2 kN

Average thickness- δ -1.3 mm

Maximum value	1.1 kN
Minimum value	1.0 kN
Dispersion	0.1 kN
Average value	1.04 kN

Average thickness- δ -1.15 mm

5. Analyze of the results

There is significant correlation between the average thickness and the average values of recorded maximal force. Average thicknesses 1.45/1.3 mm and recorded average maximal forces-correlation ratio- 92% average thicknesses 1.45/1.15 mm and the recorded average maximum forces-correlation ratio 94%. There is significant correlation above 90 %, between the average thicknesses and recorded dispersion, maximum and minimum value.

6. Sensitivity of results

Tensile testing of thin polymers frequent leads to slippage of samples during testing and significant lower results. In such cases the testing should be repeated on objectivity reasons. Some of the reasons for slippage are

- Plasticity of the materials
- Increased clearances of mechanical elements of the testing machine (bolts, nuts, pins)
- Unsuitable putting of the sample, unparallelled to the jaws
- Outworn knurls of jaws
- High speed of testing, more than the defined in the standard (50m/min)
- Untightened jaws..

Sensitivity of testing often is parallel object of analyzes with classical tool like FMEA [6].

7 Conclusion

The average thicknesses of the tested samples and recorded maximal forces according EN ISO 13426-1:2020, method B, show significant correlation (above 90%) between them. The testing according this standard and relative to its standards should be monitored very carefully because of potential slippage of the sample.

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