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Structuring key partnerships in the field of critical infrastructure security systems

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Abstract: Joint scientific and applied research occupies its place as a major innovation process in the activities of scientific, educational and business organizations. The purpose of this approach is to gain access to external sources of technology (or other assets) and their integration into products and services to build security of critical infrastructure and strategic sites of national importance.

Partnerships in the development of security systems can bring added value to partner organizations, allowing them to use a wider network of promising assets and markets and helping them gain trust and prestige in society.

The presentation of a variant of structuring key partnerships in the development of security systems is the content of this paper.

Key words: KEY PARTNERSHIPS, COMPETENCE CENTRE

1. Introduction

The purpose of building key partnerships, within the scope of Competence Centers (CCs), is to establish relationships through which to gain access to external sources of high technology (or other assets) and their integration into products and services in the field of security systems for critical infrastructures and objects of national importance. The implementation of research and innovation (R&I) in the development of security systems and the related business model (BM) makes a significant contribution in this area.

R&I refer to that part of BM that represents the ability to acquire knowledge, design, develop and improve products, services, technologies or processes. For high-tech CC partners, R&I is number one on the list of opportunities that are critical to long-term success while at the same time being the key to improving business skills, expanding the portfolio of products and services and maintaining cutting-edge applied research in the interest of the country's security.

CCs are defined as “structured, long-term research and innovation (R&I) collaboration in strategically important areas between academia and industry with frequent interactions with the public sector. A CoC focuses on strategic research agendas, support strong interactions between science and industry and provides truly collaborative research with a medium to long-term perspective” [1]. They are usually located in research organizations and focus on national strategic sectors in applied research projects in collaboration with leading business organizations.

The establishment and operation of CC in our country, such as the Project BG05M2OP001-1.002-0006 Competence Center “Quantum Communication, Intelligent Security and Risk Management Systems (Quasar)”, plays a leading role in planning, structuring and negotiating these relationships between research organizations, universities and high-tech companies.

2. Building key partnerships through competence centers

The CC's main operational objective is to strengthen partnerships between research organizations, universities and industry, thus accelerating the innovation process and leading to economic growth.

This is achieved through:

- the presence of the private sector in the management and leadership structures;
- provision of services to the private sector;
- directing the work of the academic circles to modern applied research;
- facilitating interregional relations through the participation of international companies.

Competence centers can apply good practices, separate from the work of the research and development program, with a focus on:

- use of research results through intellectual property rights and individual products;
- training of doctoral students;
- dissemination of research results through publications, conferences, etc.;
- stimulating networking and knowledge transfer;
- acquisition of funding from third countries (including EU sources);
- provision of research infrastructure;
- providing market information (TAFTIE, 2016) [1]

These good practices should offer key insights for CC management, namely:

- to be flexible in finding support and developing research projects with different funding mechanisms, for products and systems with different technology readiness levels (TRL);
- a market-oriented integrated CC must offer different types of services to promote cooperation between science and industry;
- international cooperation development through bilateral contractual applied research and development should be a strategic goal.

3. More on key partnerships

Organizations form partnerships for many reasons, and partnerships are becoming a cornerstone of many business models. Established partnerships help to optimize business models, reduce risk and acquire resources.

3.1 Motives for key partnerships

Optimization and economy of scale

The most basic form of partnership is designed to optimize the allocation of resources and activities. It is illogical for an organization (in this case a CCP) to have all the resources or to carry out every activity alone. Optimization and economies of scale partnerships are usually set up to reduce costs and often involve outsourcing or sharing infrastructure.

Reduce risk and uncertainty

Partnerships can help reduce risk in a competitive environment characterized by uncertainty. It is not logical and common for competitors to form a strategic alliance in one area while competing in another.

Acquisition of certain resources and activities

Few organizations have all the resources or carry out all the activities described by their business models. Rather, they expand their own capabilities by relying on other organizations to provide certain resources or perform certain activities. Such partnerships may be motivated by the need to acquire knowledge, licenses or access to clients.

3.2 Partnerships, the power of information sharing.

Despite the overall change in attitudes, key CC partners still have reservations about sharing information. The following main areas of concern can be identified:

- Partner organizations are concerned about the legal and regulatory implications of disclosing development information;
- Organizations are concerned about the public relations aspect;
- Organizations are concerned about the confidentiality of the data they work with.

Information security has become a risk management issue due to its potential effects. Leakage of information revealing potential results of scientific research can have legal consequences: the organization may be required to report related issues in order to comply with financial and confidentiality regulations [2]. If security issues become public, they can also harm the way the partner organization is perceived by customers and the business community, potentially affecting the profitability of the CC. For example, information sharing may reveal constructive and technological data that could potentially compromise the privacy of the affected partner organization.

The need to share security information is driven by rapidly changing businesses, technologies and threats. Increasingly, CC consists of a wide variety of key partners. We share business information and often use the same technology or sell or share technology with each other. As we do this, we also share the risks. Understanding the risks our partners face and how they manage those risks can help us protect our own organizations.

Looking more broadly into the technological landscape, all systems and devices are to some extent connected, whether owned by businesses, individuals or service providers. Almost every aspect of society depends on a global, fast-growing, extremely complex network of devices and services. This provides the central nervous system that supports innovation, economic development and social interaction worldwide. But because we are all inherently interconnected, we share common risks. The landscape of threats is dynamic, global and increasingly complex. Threats can arise in any country and then spread rapidly across national and corporate borders, causing significant damage to organizations and individuals around the world. Because threats are spreading so fast and the landscape of threats is so complex, it is difficult for any

individual organization to get a clear picture of all potential vulnerabilities, threats and attacks.

External partnerships can be useful, because they provide additional intelligence that can be used to improve the security position. By sharing information with other organizations, it can be achieved a better understanding of what is happening outside of our own environment. We learn about new threats before they affect us directly. In this way information is obtained about how other organizations are dealing with these threats and we can touch to the best practices for managing security activities. By using the information we gather from external relationships, we can increase the partner organization's ability to feel, interpret, and act on risk.

Purpose of forming partnerships

There are a number of reasons why developing a key partnership in a CCP can be beneficial. Generally speaking, partnerships can focus on a specific problem, such as developing security systems, to maintain a consistent approach to problems [3].

Some more specific reasons for forming a partnership may be:

- Achieve more efficient and effective implementation of development programs and eliminate any unnecessary duplication of effort. Gathering organizations involved in solving a problem can lead to more cohesive and comprehensive intervention. Instead of duplicating efforts, partners can share or coordinate responsibilities in ways that give more participants access to the programs and allow for a wider range of services.
- Pooling resources. Many organizations together may have the resources to accomplish a task that none of them could accomplish on their own. In general, organizations form partnerships to achieve together what they cannot do alone.
- To increase communication between groups and break stereotypes. Bringing together organizations from many sectors of the community can create alliances where there has been little contact before. Working together to achieve common goals can help organizations break down barriers and perceptions and allow them to trust each other.
- To build networks and friendships. Partnerships lead to social benefits for staff and customers, as people can build networks and friendships by participating in the organization.
- To revive the withering energy of key partners who are trying to do too much on their own. Partnerships can help step up efforts around a problem. For organizations that have worked too long in a vacuum, adding other hands to the task can be a huge source of new energy and hope.
- Planning and launching community-wide initiatives on various issues. In addition to addressing pressing security issues or promoting or providing services, partnerships can serve to pool long-term campaigns.
- To develop and use influence to obtain services or other benefits of the CC. The partnership can be more effectively advocated by different organizations working independently. In addition, a broad partnership can put pressure from all sectors of industry and have a large amount of power.
- To create long-term, permanent change. Real change usually takes place over a period of time through the process of gaining trust, sharing ideas and overcoming existing challenges in order to understand the real problems underlying the needs of industry and security. The partnership, with its structure of cooperation between different organizations and focus on solving security problems, can facilitate and accelerate the process of change, according to the dynamics of the security situation.

➤ To receive or provide services. A long-term partnership is needed to design, obtain funding within the scope of the CC's specialization.

4. Key partnerships in the QUASAR project

The partnership under the project for the Center of Competence “Quantum Communication, Intelligent Security Systems and Risk Management” (Quasar) comprises the following 8 organisations:

- Institute of Robotics “St. Ap. and Gospeller Matthew” at the BAS (Lead partner);
- Institute of Metal Science, Equipment and Technologies with Center for Hydro- and Aerodynamics “Acad. Angel Balevski” at the BAS;
- “Nikola Vaptsarov” Naval Academy – Varna;
- “Vasil Levski” National Military University – Veliko Tarnovo;
- Technical University of Gabrovo;
- Institute for Nuclear Researches and Nuclear Energy at the BAS
- Faculty of Geology and Geography of the Sofia University “St. Kliment Ohridski”;
- Association “Advanced Flight Technologies”, Sofia.

The concept for the construction of the Quasar competence center is aimed at creating a network of resources, forming a modern large-scale research infrastructure in the field of information and communication technologies, which will help achieve the goals of Bulgaria and the EU in the field of research and technological development.

The center is a set of facilities, resources and related services needed by the scientific community composed of CC researchers, but also other scientists, companies, organizations, including associate partners from our country and abroad, who will use the built infrastructure for conducting research in the relevant fields.

The research areas in which the QUASAR team specializes and work are information and communication technologies, sensorics and energy conversion, transmission of information through non-traditional channels and creation of models for events, phenomena and processes that pose a risk to the anthropogenic environment. Overcoming the interruption of radio waves and radio communications in major earthquakes, nuclear or nuclear accidents, volcanic eruptions or disasters can be overcome through the quantum communication of intertwined photons in the space-time continuum. Intelligent security systems will be able to predict accidents, disasters and prevent a terrorist threat.

Data collection will be done through micro- and nano-sensor systems based on the multisensor principle, operating in a wide temperature range. Increasing the conversion efficiency will be achieved both by lowering the operating temperature and by new modifications of the conversion elements. In general, QUASAR covers a wide market niche in communication and sensor technologies and systems

Within QUASAR, activities systematized in 4 work packages (WP) are in the process of implementation, namely:

- WP 1. Quantum communication (Leading partner: Institute for Nuclear Research and Nuclear Energy);
- WP 2. Intelligent security systems (Leading partner: Institute of Metal Science, Equipment and Technologies with Center for Hydro- and Aerodynamics “Acad. Angel Balevski”;
- WP 3. Risk management (Leading partners: the Varna Naval Academy;

➤ WP 4. Innovative sensor technologies with multi-purpose application (Leading partner: Institute of Robotics “St. Ap. and Gospeller Matthew”.

Structured in this way, the Competence Centre QUASAR has no analogue at national and European level. This is a clear niche, through which the capacity built through a key partnership will become a leading area of multidisciplinary importance. The expertise of scientists and specialists involved in the CC is such that they successfully format the innovative space of the object area of specialization with new ideas, patents for inventions and prototypes of original products and systems.

The leadership role of the team is clear as an asset and as a future potential that combines avant-garde topics: quantum communication, sensory and risk management through intelligent systems. This scope is of multidisciplinary importance and is a generator of new ideas that can be protected by patents for inventions. This is one of the few cases where a fundamental result / fundamental results of theory can lead to specific engineering solutions with a clear commercial effect. The leadership role of the thus formed scientific team is definitely proven as a potential and opportunity.

Significant contribution, as a key partner in the development of security elements and systems, including ESC, has Institute of Metal Science Equipment and Technologies with Hydro- and Aerodynamics Centre “Acad. A. Balevski”. Through its innovative developments, known and delivered to national and international partner organizations, the Institute contributes to the implementation of QUASAR activities.[3-10]

5. Conclusions

The key partnerships established through the centers of competence create relationships for the integration of the activity for the development of the products and services in the field of the security systems of critical infrastructures and sites of national importance.

Market-oriented and integrated structures, such as the QUASAR Central Committee, offer various forms of promoting structured cooperation between science, education and industry. With its organization of cooperation between different organizations and focus on solving security problems, QUASAR can accelerate the process of research and innovation, depending on the dynamics of the security environment, while helping to reduce risk in a competitive environment, characterized by uncertainty.

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Development of predictive maintenance based on artificial intelligence methods

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Abstract: Artificial intelligence become more widespread in all manufacturing subjects. In manufacturing artificial intelligence deals with such tasks as quality control, robot navigation, computer vision, processes controlling, etc. The area of maintenance in machining is a great prospect for implementing artificial intelligence tools for analysis, prediction of monitored parameters, optimization, and improvement of the quality of the maintenance process. In particular, the article refers to predictive maintenance as a modern trend in mechanical engineering. In this article, a quick review of using methods of artificial intelligence and predictive analytics in maintenance and one practical implementation case of NAR network for time-series prediction was provided.

Keywords: ARTIFICIAL INTELLIGENCE, PREDICTIVE MAINTENANCE, MATLAB, NAR NETWORK

1. Introduction

The industry is the part of the economy that produces materials and goods with a high degree of mechanization or automation to ensure the requirements for the quality of products and the productivity of the production process. Fundamental changes in technologies and methods of production, which were characterized by the introduction of new technologies at the whole stage of the development of industrialization, are now called industrial revolutions.

Nowadays, smart technologies, together with the massive introduction of information technology in the industry, large-scale automation of business processes, and the spread of artificial intelligence, create the basis for the future new industrial revolution called Industry 4.0.

When starting a new production process, a lot of attention is given to such points as the economic calculation of production efficiency, the choice of equipment, suppliers, and materials. The goal of any modern production is the productive, economical, and safe production of goods in the right volume while maintaining the desired level of quality.

At the same time, the progress of technology is causing the implementation of new highly productive machining methods, which also place higher demands on production machines and tools, their reliability, and the reliability of the production process itself.

Reliability is the ability of the equipment to perform required functions in the specified technical conditions over the operation. One of its most important features is faultlessness, which is defined as the ability of a machine to complete all specified conditions and parameters by the manufacturer's technical documentation and recommendations within the specified manufacturer's time.

And a reduction in the machine's ability to operate in a fault-free or operational mode leads to errors and defects in machine operation, production failures and can ultimately lead to faulty failures and emergencies.

2. Maintenance in the industry

The great importance of maintenance for the industry is difficult to underestimate, as its neglect is a major cause of failure and the associated costs and losses in the production process, as preventing failure is always cheaper in the end than eliminating its consequences.

The term "maintenance" according to the standard STN EN 13 306 means a summary of all activities (management, technical and administrative), the aim of which is to maintain, maintain the equipment in working order, or restore such conditions.

We often talk about maintenance strategies, which are divided into post-failure maintenance (reactive maintenance) and pre-failure maintenance. The main division of maintenance strategies is shown in Fig. 1.

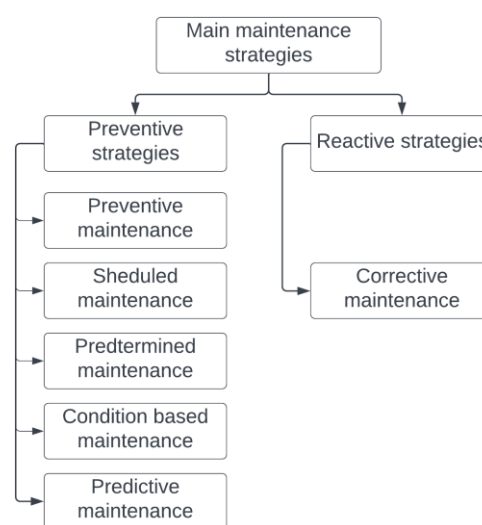


Fig. 1 The division of maintenance strategies

The main goal of maintenance is to maintain the operability of the machines, which means ensuring the smoothest possible operation of the production process, minimizing the time of production interruption, and eliminating the negative consequences of machine downtime. Maintenance goals also include achieving and extending the planned technical life of production machines, minimizing threats to environmental damage, and preventing occupational accidents and health [2].

3. Predictive maintenance as a modern trend

The obvious advantages of preventive maintenance over reactive maintenance are, for example, a lower risk of failures that will cause a long-term shutdown of the equipment, a reduction in the risk to the health and life of workers working with the equipment. The possibility of maintenance planning in connection with planned outages causes a significant reduction in maintenance costs. However, the maintenance interval specified by the manufacturer is not always optimal and appropriate for a particular operation, and the separate determination of such an interval may be associated with downtime risks and unforeseen costs.

Predictive Maintenance (PdM) deals with the problem of determining the correct length of maintenance cycles. The goal is to schedule maintenance at the most convenient and cost-effective time to optimize equipment life before the equipment will be

damaged. Unlike preventive maintenance, the maintenance of each device is assessed and planned based on the current state of the device. The basis of predictive maintenance is perfect "condition monitoring" - using a summary of certain measured physical parameters (such as system pressure, temperature, vibration, etc.), the current state is determined continuously. Furthermore, based on these data, we use statistical and artificial intelligence methods to try to estimate the failure time. With this procedure, we enable a sharp reaction to a change in the condition of the equipment, and subsequently, depending on the real situation, it is possible to extend or shorten the maintenance cycle for a specific machine.

Predictive maintenance is a current trend in the industry, as predictive maintenance is in principle more effective than preventive maintenance because it is based not only on the actual current state of the equipment but also on the historical load and considers other factors. It also reduces the number of unplanned downtimes, increases productivity, reduces the cost of maintaining operability, and increases the safety of the production process

4. Artificial intelligence and machine learning in PdM

Unlike traditional maintenance procedures that rely on the life cycle of machine components, a predictive approach based on the principle of machine learning prevents the loss of resources and insufficiently optimized use of resources for maintenance tasks.

Artificial intelligence in predictive maintenance can adapt routine maintenance activities to the needs of each device. The implemented artificial intelligence system can be taught to visually identify errors and patterns in the device, can follow the instructions of a computer-aided design without further programming of the system, and even use the currently obtained data for subsequent training and real-time model improvement. Automatic anomaly detection reduces unplanned downtime and costs by quickly providing an estimate of when a device will fail. Successfully implementation of artificial intelligence for predictive analytics tasks is shown in [3-5].

In terms of predictive maintenance of machines and equipment, continuous monitoring has great importance. By using the sensor on the investigated machine, it is possible to create a mass of data on the state of the device continuously in time. These, in turn, together with the historical data after establishing the dependencies between the normal and faulty states of the system and the corresponding parameters, already allow the top of the prediction model.

The maintenance interval prediction task is essentially a time series prediction task. The time series is arranged according to the time of occurrence of the series of quantities of some investigated parameter. The values of the examined parameter are usually recorded in equally long-time intervals. The time series is used to monitor time changes and monitor trends in the development of the examined parameter. Furthermore, changes to any parameters are chaotic because they change randomly in the real world.

The most used in research and practice models for time series prediction are linear autoregressive models (AR and ARX), moving average model (MA), autoregressive moving average (ARMA), LSTM neural networks model, and nonlinear autoregressive (NAR and NARX) neural network models.

AR and ARX models were successfully implemented for example in [6,9] for regulation of the climate parameters in buildings and greenhouses. Among the main benefits of the ARX model is the simple structure of the model - a small number of model parameters, simplicity of interpretation of model parameters, and simplicity of possible integration of the model into the control system. However, ARX models are not able to estimate nonlinear dependencies.

The ARMA (autoregressive moving average) model class can be used to solve problems in engineering, economics, and the natural sciences, which have a large amount of data where the observed quantities are interdependent. The models can be used for both deterministic and stochastic modeling using historical data and prediction errors to generate forecasts, dynamic analyses, and other statistical information with a minimum number of parameters used to represent system dynamics.

Algorithms that use ARMA models for prediction show good results for short-term prediction and this can be seen in studies [8,10], but the accuracy of the model decreases significantly as the time for which parameter values need to be predicted increases. The response tends to over-reproduce the average of values observed in the past. In addition, these methods work with homogeneous time series, where input and prediction are within the same set of values.

All the above models can be used to construct the recurrent neural network (RNN) for time-series prediction. However, they have a problem storing and spreading errors in time. It happens because the backpropagated error either disappears quickly or increases sharply, as the magnitude of the error signal propagated back in time depends exponentially on the size of the scales.

This problem can be solved by using long-short time memory (LSTM) networks. The structure of the LSTM neural network consists of cells (Fig. 2), which are formed by an entrance gate, an exit gate, a forgetting gate, and a memory cell.

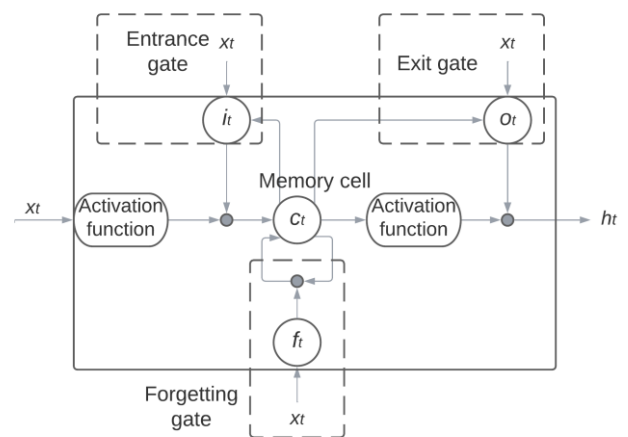


Fig. 2 The LSTM cell structure

Using the LSTM network allows tracking the dependencies of new observations with past (even very distant) ones. However, this capability, due to the tendency of the cell state values to increase linearly (especially when observing a continuous data flow), can cause the LSTM module to fall into a normal error backpropagation network. This means that the main ability - to keep the error in time will be eliminated. In general, LSTM models are complex and are rarely used to predict a single time series because they require a large amount of data to be estimated. However, they are commonly used when predictions are needed for many time series [1].

One of the modern and most widely used time prediction methods is prediction using NAR (Nonlinear Autoregression) and NARX (Nonlinear Autoregression with exogenous inputs) neural networks.

A NAR neural network is a type of dynamic neural network based on time series. The relationship between the input and output variables of the model is not just a static mapping, but the output of each moment is synthesized based on the dynamic results of the system before the current moment, so it has a feedback and memory function.

In the case of a neural network NAR, the delayed time series values are used as inputs to the neural network. The output from the neural network is a predicted value, corresponding to the value of the parameter that needs to be predicted at a certain point in time[5].

5. An example of time-series prediction using NAR network

To visually illustrate the predictive ability of a nonlinear autoregressive neural network to make predictions, a simple model was developed in the MATLAB software package to predict the magnitude of the output signal for acceleration data.

To generate a gyroscopic dataset an M5-StickC microcontroller (see Fig. 3) was used.



Fig. 3 The M5-StickC microcontroller

The M5-StickC microcontroller can read acceleration along the X, Y, and Z axes as well as gyroscopic data in the same axes at a frequency of 18 measurements per second. The created data set was then saved in .csv format.

Before entering the neural network, data must be pre-processed to eliminate error values and possible completion of missing points. The result is shown in Fig. 4.

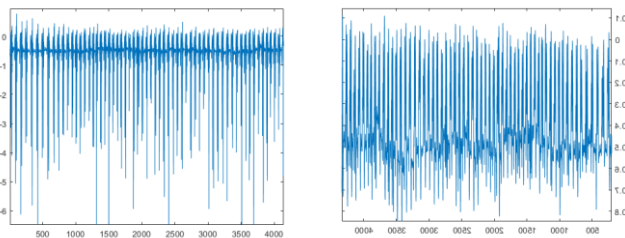


Fig. 4 Data before pre-processing (left) and after pre-processing (right)

The Designed NAR network consists of the input layer, 3 hidden layers with tangent sigmoid function as an activation function, and the output layer with linear function as an activation function. The structure of the neural network is shown in Fig. 5.

For time series prediction tasks, the NAR neural network architecture, unlike conventional recurrent networks, is designed as a time-delay neural network (TDNN). It means that the output of each moment is synthesized based on the dynamic results of the system before the current moment, so it has a feedback and memory function.

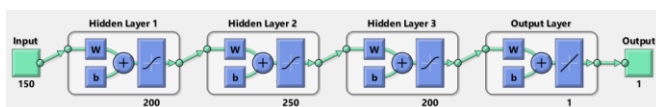


Fig. 5 The structure of the designed NAR network

After creating the training dataset, the neural network was trained, and a one-step-ahead prediction plot was built. In Fig. 6 prediction values (orange plot) and real-time values (blue plot) are shown for one-step prediction.

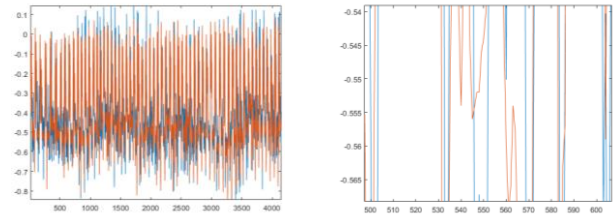


Fig. 6 Predicted and real-time values

6. Results and discussion

The proposed neural network model showed a high preliminary result for predicting the values of the time series. When predicting one step, the prediction accuracy reached 90%. This is illustrated by the regression plot (Fig. 7).

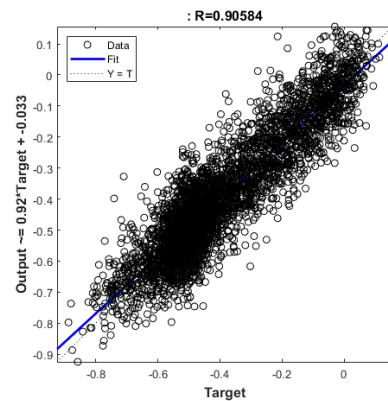


Fig. 7 Regression plot for one step ahead prediction

However, in the case of predicting more steps, the accuracy of the proposed model dropped significantly (see Tab. 1).

Tab. 1 Accuracy of proposed neural network

Number of ahead prediction steps	Correlation coefficient value
5	0,76
10	0,57
20	0,28

As can be seen from Tab. 1, the predictive accuracy for predicting 20 steps is approximately 28%, which means that the accuracy for using the proposed neural network in practice for predictive maintenance tasks is not suitable.

The decrease in accuracy can be due to the insufficient quality of the data taken - the data acquisition technique did not assume a cyclic change in the parameters, and because of this, the parameters were chaotic. It is possible to partially eliminate this disadvantage with the help of better data pre-processing. However, the methodology for obtaining data needs to be developed more carefully.

Another possible reason for poor prediction may be the architecture of the neural network itself. It is probably worth trying to use a different number of hidden layer neurons and the number of layers itself, as well as other activation functions.

7. Conclusion

In this paper, a brief analysis of artificial intelligence models used for predictive analytics in predictive maintenance tasks was made. A model was proposed, and an example was given of using a neural network with non-linear autoregression to predict the behaviour of acceleration data along with one of the axes.

Experimental data showed insufficient reliability of the proposed model for real practical problems. The presumably negative results were contributed by the chaotic nature of the data (the stable dependence of the microcontroller readings on the moment in time in the future) and the too simple structure of the neural network. In the future, it is planned to develop another neural network model with non-linear autoregression for a more accurate forecast and the possibility of using such a model in practice.

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Development of menstrual panties within the framework of sustainability and creation of a start-up

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Abstract: Direct At the Technical University of Liberec, Faculty of Textiles, there was a cooperation between this state university and a small private company. The cooperation was created for the development of sustainable aids for menstrual periods. All development took place at the university, including the search for local production partners, and the private company financed the development. The output is a utility model owned by the university and the private company, and in addition the private company pays the license fee. The article describes in more detail this cooperation, as well as the development and the developed product, up to its actual commercialization.

Keywords: SUSTAINABILITY, START-UP, layer,

1. Introduction

Menstrual panties are another alternative for women during their periods which aims at increasing the women's feeling of comfort. Another advantage is their sustainability, as it is an aid that can be used repeatedly, unlike the still widespread tampons and pads. Their advantage is the possibility of being washed and reused. In his article, Parent focuses on hygiene aids, including menstrual panties, and the public awareness about them in France. The reason for this study was that no work had been done on this topic so far. In conclusion, the author points out that there is a growing interest in these products among the French public [1]. Medina-Perucha deals with menstrual aids in her work, both disposable and multi-use ones. Respondents were more in favour of the re-usable products. Her work also points out common problems with menstrual cups [2]. The author de Belleville points out common problems with menstrual aids in India and compares India with France. In France, a woman has several types of protection to choose from, whereas in India, only 12% of women have access to protective equipment during their menstruation. Other women use rags and other textile waste [3]. The Stockburger MD describes menstruation and the possibilities of its suppression, but also describes the aids available for menstruation, including menstrual panties. He mentions that all devices have their advantages and disadvantages [4]. Marcellis has dealt with various menstrual aids, including menstrual panties, and a system for evaluating the effects of excreted substances on the skin of the body [5].

The research shows that there are already several manufacturers that manufacture and sell menstrual panties and those are perceived as a positive protection alternative during a woman's period. At the same time, thanks to the possibility of repeated use they seem to be very important for developing countries, where classic disposable aids are just not available.

The development of menstrual panties took place from the very beginning with the emerging start-up, which did not yet have any legal form of business. All development took place at the Technical University of Liberec and the start-up (natural persons) paid for the individual stages of the development. After the successful completion of the first prototype, SaYu s.r.o. (legal entity) was created. The SaYu company, in cooperation with the Technical University of Liberec, arranged production by Czech manufacturers and suppliers. After the completion of this stage a common utility model was created, which is owned by SaYu and the Technical University of Liberec. It is this connection between a university and a company and the creation of a successful product which represents a typical example of a successful transfer.

2. Materials Development of menstrual panties

At the time when the development of menstrual panties began at the Technical University of Liberec, these products already existed, but unfortunately, they had great limitations, especially in terms of their thermo-physiological comfort properties. These were mainly hydrostatic resistance (water column height), vapor permeability and low absorbency. Therefore, the development was focused

mainly on finding suitable layers for menstrual panties. Menstrual panties consist of four basic layers. Figure 1 shows a diagram of menstrual panties and their functional layers. Menstrual panties as developed at the Technical University of Liberec have the task to perfectly remove any moisture from the skin, to transfer excess moisture into the absorbent layer and at the same time there is another layer - a nanofiber membrane. The task of the nanofiber membrane is not to let through excess moisture, but at the same time the membrane must be very vapour-permeable.



Fig. 1 Functional layers of menstrual panties

1st layer – transport layer (transports fluids as fast as possible into the next layer)

2nd layer – absorbent layer (highly absorbent and also spreading moisture along the absorbent core)

3rd layer – protective layer (membrane – provides high hydrostatic resistance and at the same time excellent vapour permeability)

4th layer – visible aesthetic layer (the same material as is used for the other parts of the complete final product)

Fabric liquid moisture transport properties in multi-dimensions, called moisture management properties influence the human perception of moisture sensations significantly. Some standards and test methods can be employed to evaluate the fabric's simple absorbency and wicking properties, and the liquid strike-through time of nonwovens also can be tested according to ISO 9073-8. However, the existing standards cannot measure the behavior of fluid transfer of the clothing materials dynamically [6].

The MMT measures textiles' dynamic liquid transport properties, such as knitting and woven fabrics. A series of indexes are defined and calculated to characterize the liquid moisture management performance of the test specimen [7].

3. Results and discussion

Transport layer

In this layer, rapid transport of fluid from the wearer's skin to the absorbent core is particularly desirable. Functional knits based on shaped fibres such as PES, POP or WO are particularly suitable for this purpose. In the case of the development of menstrual panties, a knit of 100% merino wool with areal weight of 105 g / m² was chosen. The moisture transport rate is best expressed by measuring the absorbency value of the sample [% · s⁻¹] on an MMT instrument (Moisture Management Tester). The device MMT measure according to the standard AATTC 195 - Moisture Management Tester

At the same time, however, this material is not suitable for the second absorbent layer, precisely because of the low moisture distribution in the area. Table 1 shows the measurement results for the transport layer and Figure 2 shows the spread of moisture over time.

Table 1: The measurement results for the transport layer.

WASHED SAMPLES		Sample No. 3
		Double-face
Wetting time [s]	Top side	7.7
	Bottom side	45.4
Absorbency [%/s]	Top side	210.7
	Bottom side	10.8
Maximum wetting radius [mm]	Top side	5
	Bottom side	8.3
Solution-spread rate through the fabric [mm/s]	Top side	0.67
	Bottom side	0.65

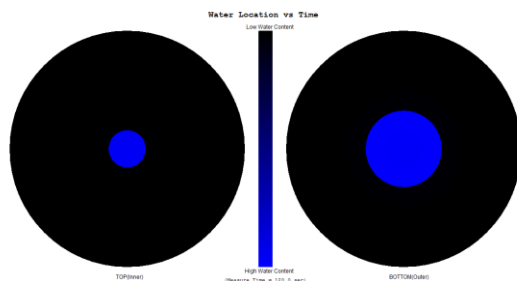


Fig. 2 Moisture spreading in time for the transport layer.

Absorbent layer

For the first layer - the tactile one - the rapid transport of fluid from the wearer's skin towards the absorbent core is most desirable. However, for the second layer – the absorbent one - the level of moisture distribution is very important. 100% cotton was selected for this layer, which has these desired properties. Because it is only the second layer, which is not in contact with the wearer's skin, it can be just knitted fabrics like cotton with a real weight of 165 g / m². Table 2 and Figure 3 show the specific results.

WASHED SAMPLES		Sample No. 4
		Double-face
Wetting time [s]	Top side	4.5
	Bottom side	5.3
Absorbency [%/s]	Top side	45.6
	Bottom side	51.4
Maximum wetting radius [mm]	Top side	20
	Bottom side	20
Solution-spread rate through the fabric [mm/s]	Top side	3.69
	Bottom side	2.93

Table 2: The measurement results for the transport layer.

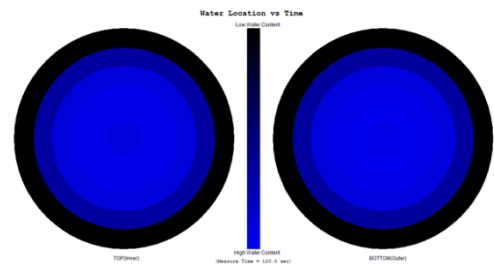


Fig. 3 Moisture spreading in time for the transport layer.

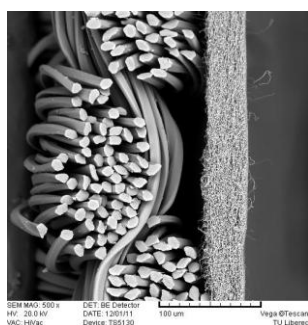
Protective layer

A nanofiber membrane was used as the protective layer. Laboratory production of nanofiber membranes was performed on the Nanospider machine. A polymer solution was added to a basin with a rotating roller. This solution was exposed to an electro field of $U = 76.1$ kV voltage. A collector was placed above the basin at the distance of 175 mm for the first sample and at the distance of 130 mm for the second sample. The speed at which the base material was moving was set at $v = 0.1$ m/min. The relative humidity in the spinning chamber was regulated at 21%. The humidity sensor was not placed directly in the spinning chamber, but in the tube bringing the air to the chamber to ensure proper sealing. The turning of the roller (driven by a rotor) in the basin created a thin polymer solution layer on its surface from which in turn nanofibers were formed due to the high voltage and collected on the support-material. The mass per unit area of the created nanofiber layer was 5 g/m².

Subsequently, a two-layer laminate was created because a simple nanofiber layer would be easily damaged. For the 2 -layer laminate a warp knitted fabric was used (warp knit with a real weight of 29 g / m², to affect the thermo-physiological comfort of the nanofiber membrane as little as possible) with lamination points and a nanofiber layer, which was still on the base material. When laminating the top material and the nanofiber layer, the size of both materials was 50x50 cm. A nanofiber layer was put on the top material from the side with the lamination points. The resulting structure was placed on the lower part of the body of the Kannegiesser gluing machine and the required pressure of 3 bar was applied on the upper part of the body for 15 seconds at a temperature of 120 ° C. Thanks to these parameters, the polymer dots on the top fabric melted and a solid 2-layer laminate was formed, which can be seen in Fig. 4 taken by a scanning microscope. The base material is later pulled off.

Table 3: The measurement results for the transport layer.

WASHED SAMPLES	Sample No. 5
	2-layer laminate
Steam permeability Ret[Pa.m ² .W ⁻¹]	2.4
Air permeability [l/m ² /s]	1.865
Hydrostatic resistance [mm]	10 340
Number of washing cycles before delamination	95
Joint strength [N]	36.7

**Fig. 4** Two-layer laminate cross-section.

The results show that the nanofiber membrane resp. laminate with a nanofiber membrane achieves very good values of thermo-physiological comfort.

3. Conclusion

The results show that the task was to develop menstrual panties with maximum emphasis on their thermo-physiological comfort during periods, meaning that all layers should be as vapour-permeable as possible to make women feel as comfortable as possible while wearing them. At the same time, the development took into account that women should not feel anything during menstruation which means that the first layer has the task of removing moisture from the woman's body as quickly as possible, the second layer has the task of absorbing the excess moisture, so a knitted cotton fabric was chosen. The next layer is a two-layer laminate so that there is no unwanted leakage. However, unlike other commercial panties, a nanofiber membrane was used. Other manufacturers most often use simple coating which has very poor vapour-permeability and lower hydrostatic resistance, properties essential for enabling active movement during a period. Thanks to the development of this product, unique cooperation between the Technical University of Liberec and the SaYu company was created, which at its beginning was a typical start-up, but a successful one. Thanks to this cooperation, joint intellectual property was created in the form of a utility model, where SaYu pays regular license fees for each piece sold. The Technical University of Liberec does not cooperate with anyone else in this field, and SaYu thus has exclusivity in the further development of menstrual panties. This created a model example of cooperation between a state university and a private company. This article wants to show that it is possible not only to start, but above all maintain a long-term cooperation between a state university and a private company.

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Financial project for construction of a plant for the production of granules, panels and plates of foam glass and small and large composite elements

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Abstract: A financial project has been prepared for the construction of a plant equipped with a technological line for the production of foam glass products. It is planned to build a warehouse for raw materials, a sector for preparation of materials, various production workshops for the manufacturing of foamed granules and pieces, a continuous tape or block of foam glass, various composite materials (thermal insulation and color decorative panels, various small and large composite elements, etc.), repair section and two warehouses for finished products. Approximate calculations have been made for the necessary raw materials, technical equipment, electricity, personnel and other costs for the realization and operation of the plant.

Keywords: FOAM GLASS, FINANCIAL PROJECT, EQUIPMENT FOR THE PRODUCTION OF FOAM GLASS, COMPOSITE MATERIAL

1. Introduction

The modern intensive development of materials science, accompanied with the conduct of multidisciplinary fundamental [1-5] and applied research [6-12], allows the elaboration of innovative functional products with diverse uses in various fields [6-10].

A number of author teams study the amorphous structure [1-5,13,14], properties and possibilities for application of various vitreous materials [6-8,15]. Specific environmental and technological interest is the successful recycling of existing quantities of waste silicate glass (of various origins) and the production of cost-effective products such as foam glass and others.

Foam glass materials are non-combustible, durable, characterized by appropriate thermal insulation and mechanical properties, chemical resistance, high thermal stability [6-8] and retain their functional qualities under the influence of various weather conditions [8] and cyclical climate change [6,8,16,17]. According to its complex operational indicators foam glass products are significantly superior to some thermal insulation products for construction [8], which have gained wide popularity in recent decades.

The presented development for the construction of a factory equipped with a technological line for the production of foam silicate materials is based on the research experience gained in the implementation of several research projects, the elaborated current inventions [18,19] and the numerous additional laboratory tests performed [6-8].

This publication discusses some economic indicators needed to prepare a realistic business plan for the construction of a plant (Fig.1) for the production of various foam glass products: sound and heat insulation boards (for walls, ceilings, floors, equipment, etc.), colored decorative panels for cladding buildings, bulk granules of FG, small and large structural elements (with II- and semi-O-shape), applicable in construction, shipbuilding, industry, energy, etc. The fabrication of various composite materials with reinforcement is envisaged, providing higher mechanical stability and allowing partial bearing function of the final products. The total investment value for the construction of the plant of 2 million euros has been determined, on the basis of which calculations have been made for the prepared business plan.

2. Some financial parameters

2.1. Determining the needs of the product for a period of 10-15 years - marketing analysis

After consultations with specialists, independent research was made, approaching reality. The investigation plan includes the following parts:

The aim of the research

The aim of the marketing research is to prove the need for the product "foam glass" (FG) and the opportunity to establish itself on the market, both in Bulgaria and abroad. The need for the product is

proved by its technical indicators, and the imposition of the market depends on the needs, company policy, advertising, economic opportunities of consumers and more.

Methodology for selection of clients - through quotas

In construction

Bulgaria ranks last in Europe in the production of thermal insulation materials for construction. In our country, there is a recent practice, as in other countries, to insulate residential, industrial and social buildings, in order to reduce heat loss and save energy.

The significance of the problem for the thermal protection of external, enclosing structures and the building as a whole requires special design of the thermal insulation, which is a separate part in the design of the building.

The effort is aimed at determining the possible volume of orders from construction companies. The average volume of housing construction taken from the statistical directory for the last three years is 38,000 new dwellings per year, 26,000 for cities and 12,000 for villages. Given the stagnation of the economy, we hope that this volume will be maintained and gradually increase in the period of reaching the maximum production of the new plant. These are an average of 400 residential buildings with 40 - 80 homes built on 1000 sq.m built-up area of 5 to 8 residential floors and 100 sq.m per dwelling. For the thermal insulation of 1 such building an average of 3000 sq.m of insulation boards with a thickness of 50 mm are needed for the external walls, first and last slab. When insulating elevator cages, shafts, corridors, ceilings, etc. unheated premises the volume of consumption increases to 4500 sq.m, which is equal to 225 cubic meters. If this material is also used for sound insulation of each floor slab, the required volume is 400 cubic meters of thermal insulation for a residential building in the city. In the villages, an average of 25 cubic meters of thermal insulation is needed for a single-family house with 100 sq.m of built-up living area. The total required consumption for housing construction is estimated at about 210,000 cubic meters of thermal insulation per year.

It is assumed that half of this volume will not be realized due to conservatism and economic reasons. We distribute the other half among the existing manufacturers of insulation and construction materials (Table 1) - expanded polystyrene (EPS), extruded polystyrene (XPS), wood fiber insulation boards, mineral wool, gypsum fiber boards, aerated concrete blocks of the company "Ytong", foam concrete, expanded clay concrete, perlite concrete, perlite slabs, loose perlite, insulating screeds (perlite, vermiculite, expanded clay) etc. Although the performance characteristics of foam glass are superior to most of the listed insulation materials in the present study we determine equal quotas for various alternative of FG products 7.5% of 210,000 approximately 16,000 cubic meters of FG per year.

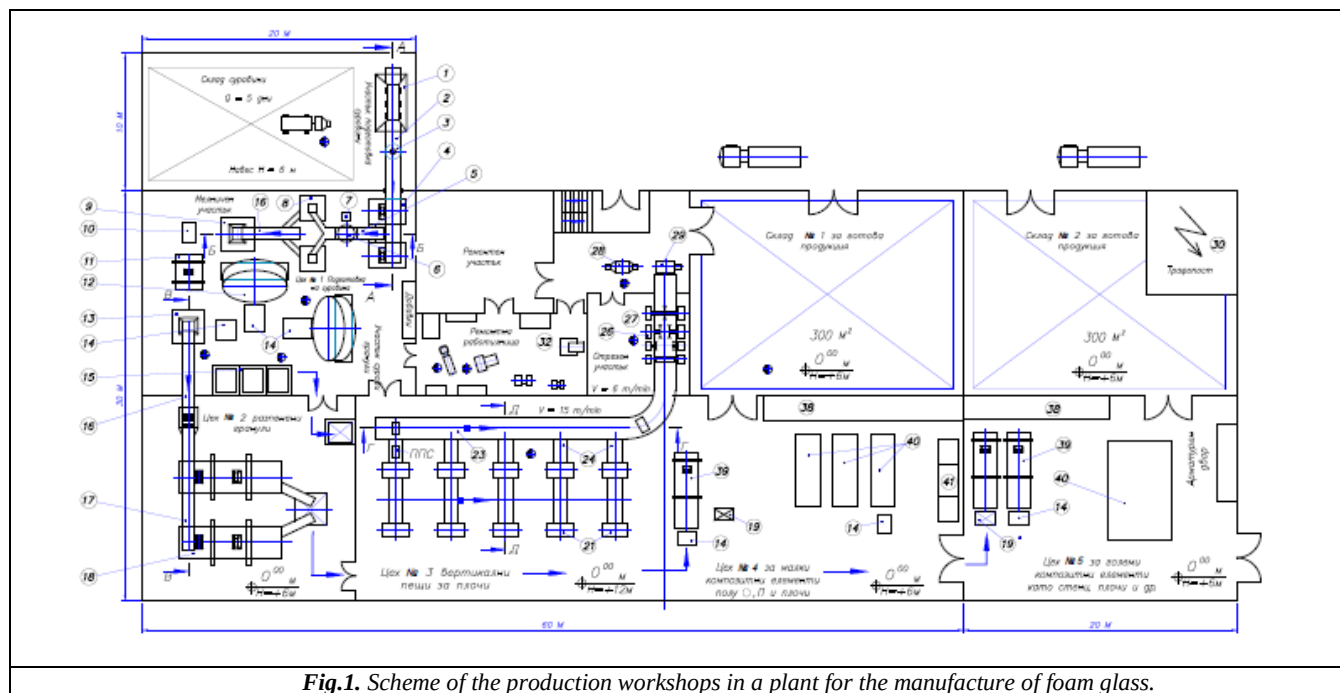


Fig.1. Scheme of the production workshops in a plant for the manufacture of foam glass.

For public construction such as hospitals, clinics, kindergartens, etc. public buildings (also from the statistical directory) the volume of construction is approximately 30,000 sq.m built-up area, equal to approximately 30 residential buildings, as described above, i.e. 12000 sq.m of insulation material or 1000 cubic meters of annual consumption of FG for public construction.

The volume of industrial construction is also insignificant compared to that for housing construction. It is accepted as 20% of it, i.e. 1500 cubic meters. Total for construction 18500 cubic meters.

In shipbuilding

A classic option for the use of foam glass as an insulating material is the sphere of shipbuilding. In the experimental - industrial production of FG in 1971, almost the entire amount of foam glass produced was used at the equipment of vessels. Due to the closure of our shipyards is planned. annual consumption of approximately 1,000 cubic meters.

In energy

In the energy sector, foam glass products with a specific shape are used, mainly halves of pipes for insulating pipelines of different diameters.

Table 1. Competitive materials.

No	Competitive materials	Market shares, %
1	Brick masonry (without thermal insulation)	50
2	Aerated concrete, foam concrete, perlite concrete, expanded clay concrete,	15
3	Effective thermal insulation materials	
3.1.	Perlite slabs	7.5
3.2	Insulating screeds (perlite, vermiculite, expanded clay, etc.)	5
3.3	Expanded polystyrene (EPS), extruded polystyrene (XPS)	7.5
3.4	Mineral wool	2.5
3.5	Wood fiber insulation boards	2.5
3.6	Foam glass	7.5
3.7	Others	2.5

At the same time the plates from FG are used for rectangular ducts of pipelines, for lining of chambers and rooms with specific functions, insulation of facilities and others. The annual

consumption of FG in the energy sector is estimated at 2000 cubic meters.

Table 2 shows the volumes of annual consumption (in the minimum version) in the various branches of industry.

Table 2. Areas of application.

No	Areas of application	Volume, cubic meters
1	Construction	
1.1	Residential construction	16,000
1.2	Public construction	1,000
1.3	Industrial construction	1,500
2.	Shipbuilding	1,000
3.	Energy	2,000
4.	Export abroad	5,000
	Total	26,500

The total required volume is 26,500 cubic meters FG

A suitable product for export abroad is the so-called "sandwich" type panels made of wooden or composite exterior panels and an insulating layer of FG, applicable in the construction of thermal insulation systems of small family houses. When participating in exhibitions, an increased interest was registered (by many construction companies) in this type of panels.

A capacity of 8,000 cubic meters is envisaged for the first stage and a doubling of production for the second stage to 16,000 cubic meters per year. It is insufficient to meet the full needs of the FG. After the implementation of the project, appropriate management decisions can be made to change the volume of production, but at the beginning of the activity it is advisable to work in a market with greater opportunities for implementation. It is assumed that in the next 10-15 years the FG plant will operate at full capacity.

Production program

The initial production program was determined through the marketing analysis, as a basis for calculating the productivity of the technological line.

The production program envisages planning the capacity of the technological line with the necessary reserve for scrap (in small volume), taking into account the necessary scheduled repairs of facilities and all other prerequisites for regular, complete and trouble-free operation of the plant for production of FG. Table 3 presents the production program for a 10-year research period, comparable to the real life of the technological line and the real cycle of production development. In the first year it is planned to

design the plant and carry out a number of preparatory activities. The construction of the building and installation of the necessary equipment is carried out for a period of half a year.

Table 3. Production program.

Years	Production
1*	8,000
2	16,000
3	16,000
4	16,000
5	16,000
6	16,000
7	16,000
8	16,000
9	16,000
10	16,000

2.2. Analysis of the consumption of raw materials and auxiliary materials - waste glass, foamers (foaming agents), modifiers, colorants, etc. Material and heat balance of production.

Main raw material - waste silicate glass

The required amount of basic raw material (with 20% stock) for the production of PS with a specific weight of 130 to 180 kg/cubic meter has been determined. The mode of operation of the main equipment of the technological line - the vertical shaft furnace 5 pcs and the rotary kilns 2 pcs is continuous. Annual production estimates have been made for a period of 330 working days. An additional 35 days are provided for scheduled repairs. The daily, monthly and annual consumption of raw material with 20% reserve at a minimum density of 130 kg / m³ and a maximum of 180 kg / m³ was determined (Table 4). Calculations as cost norms are made for the maximum density.

Table 4. Consumption of raw materials

Productivity cubic meters		Consumption of raw materials - glass shards in kg		
		Daily	Monthly for 27.5 working days.	Annual for 330 working days
8,000	min	4,920	135,300	1,623,600
8,000	max	5,250	144,375	1,732,500
16,000	min	9,840	288,750	3,247,200
16,000	max	10,500	288,750	3,465,000

Consumption of foamers (foaming agents), colorants and modifiers

Soot up to 3% (pure, imported) is used as a foaming agent in the production of FG, coloring the obtained product in black. At the same time in the role of foamer it is possible to use glycerin (coloring the obtained material in black), calcium carbonate (coloring the obtained material in white) and others. At preparing the compositions sodium silicate 3%, various colorants (if necessary 2, 4 and 6%), suitable modifiers (TiO₂, etc.) etc. are introduced. In the implementation of the present project it is envisaged the application as foaming agents mainly of glycerin in the production of black foam glass (for the preparation of thermal insulation products) and of CaCO₃ together with pigments for the manufacturing of colored foam glass for the obtaining of decorative panels for cladding of buildings.

Table 5. An expert assessment for a price of 1 cubic meter for materials.

8,000 m ³ /year	MIN	3.0648 EUR/M ³
	MAX	7.9248 EUR/M ³
16,000 m ³ /year	MIN	3.0648 EUR/M ³
	MAX	7.9248 EUR/M ³

Production packaging

The packaging of the produced FG plates is carried out on pallets with dimensions 800x1200x150 mm. The stacking of the FG plates on the pallets is done by the palletizing machine at the end of the technological line, if necessary they are wrapped in

polyethylene foil (according to the customer's requirements), tied with a strap and stored. The height of the finished pallet is 2 meters. For other types of products, it is also possible to apply the presented packaging procedure.

2.3. Electricity consumption by consolidated indicators

The electricity consumed (table 7) is divided into two groups: electricity used for preparatory and final operations and basic electricity for heating, foaming and stabilization of the resulting foam glass. The first group is carried out by the various equipment described in the title list of the technological line, and the second group is carried out by the heaters of the two furnaces numbers 18 and 21 of the title list. With a productivity of 8,000 cubic meters per year for the first stage and 330 working days per year, the daily productivity is 24 cubic meters of boards and granules, and with 16,000 cubic meters for the second stage, respectively 48 cubic meters. In the table. 6 shows the power consumed by all consumers on the production line, with the same numbering from the title list. Some facilities do not have electricity consumption. The price of the ENERGY consumed is 0.15 EUR / kWh for a three-tariff electricity meter (average value of 0.22: 0.14 and 0.09 BGN per kWh for 2020). If necessary, it is possible to use gas as a heat carrier.

Table 6. Total power used.

Power	3a 8 000 m ³ /year	3a 16 000 m ³ /year
1. Total installed power of machines for preparatory - final processing	243 kW	310 kW
2. Total installed power for heating and foaming	470 kW	940 kW
3. Total daily power used without heating the material for preparatory - final processing	641 kWh/ day	1,119 kWh/ day
4. Total annual power used without heating the material for preparatory - final processing	211,530 kWh/year	369,270 kWh/year
5. Total power used for preparatory - final processing for 1 m ³	26.4 kWh/m ³	23.4 kWh/m ³
6. Total daily power used to heat and foam the material for 12 hours (with on and off to maintain the temperature) - max	5,640 kWh/day	11,280 kWh/day
6a. Total daily power used to heat and foam the material for 8 hours (with on and off to maintain the temperature- min	3,760 kWh/day	7,520 kWh/day
7. Total annual power used to heat and foam the material - max	1,861,200 kWh/year	3,722,400 kWh/year
7a. Total annual power used to heat and foam the material -min	1,240,800 kWh/year	2,481,600 kWh/year
8. Total power used for heating and foaming the material for 1 m ³	232.65	232.65
9. Total power used for preparatory and final processing and for heating and foaming of the material for 1 m ³	26.4 + 232.65 = 262 kWh/m ³	23.4 + 232.65 = 259 kWh/m ³
10. Total annual power used for preparatory and final processing and for heating and foaming the material - max	2,096,000 kWh/year	4,144,000 kWh/year
10a. Total annual power used for preparatory and final processing and for heating and foaming the material - min	1,452,330 kWh/year	2,850,870 kWh/year
11. Total value for 1 cubic meter in Euro - max	39.3	38.85
11a. Total value for 1 cubic meter in Euro - min	27.23	26.73

The annual consumption is calculated for a period of 330 working days, with some facilities operating in one, some in 2 shifts, and furnaces in a continuous cycle of work (3 shifts). Consumption of other types of energy (for heat, cooling, water, steam, fuel, etc.) is not except for household needs - 1 EUR/m³.

Table 7. Total power consumption.

№	Installation	Number	Installed power	Productivity 8,000 m ³		Productivity 16,000 m ³	
				Time for work	Power consumption	Time for work	Power consumption
			kW	h	kW	h	kW
1.	Supply hopper	1	-				
2.	Conveyor	1	1x2.2=2.2	3	6.6	6	13.2
3.	Shower for washing glass waste	1	-				
4.	Crusher - vibrating	2	1x2.8=2.8 2x2.8=5.6	5	14	5	28
5.	Conveyor	1	1x2.2=2.2	3	6.6	6	13.2
6.	Electromagnetic separator	1	1x10 =10	3	30	6	60
7.	Non-glass waste hopper	3	-				
8.	Waste glass mill	2	1x3.6=3.6 2x3.6=7.2	12	43.2	12	86.4
9.	Sieve vibrating flat closed	1	1x4=4	5	20	10	40
10.	Cart for additions with scales	1	-				
11.	Homogenizer	1	1x2.2=2.2	6	13.2	12	26.4
12.	Granulator	2	1x2.2=2.2 2x2.2=4.4	6	13.2	12	26.4
13.	Hopper for feeding raw granules	1	-				
14.	Trolley with trays for drying ready-made raw granules	6	-				
15.	Dryer for raw granules	1	1x6=6	8	48	16	96
16.	Scraper conveyor for raw granules	2	1x2.2=2.2 1x2.2=2.2	3 3	6.6 6.6	6 6	13.2 13.2
17.	Conveyor belt for carrying	1	1x1.1=1.1	3	3.3	6	6.6
18.	Rotary furnace for foaming raw granules	2	1x10=10 2x10=20	8	80	8	160
18a	For heating the material - for 24 hours works 8 (12) hours	2	1x120=120 2x120=240	8 (12)	960 (1,440)	8 (12)	1,920 (2,880)
19.	Hopper for feeding foamed granules	4	-				
20.	Packaging machine for foamed granules in bags of 25 kg.	1	1x10=10	2	20	4	40
21.	Vertical shaft installation (without automation)	5 10	5x2.5=12.5 10x2.5=25	1	12.5	1	25
21a	For heating the material - for 24 hours works 8 (12) hours		5x70=350 10x70=700	8 (12)	2,800 (4,200)	8 (12)	5,600 (8,400)
22.	Container feeding installation with the batch	10	-				
23.	Rolgang main	1	1x6=6 1x6=6	16	96	16	96
24.	Rolgang under the furnaces	5	5x2.2=11 10x2.2=22	0.34	3.74	0.68	7.48
25.	Aspiration system around each vertical furnace	1	5x1.1=5.5 10x1.1=11	24	132	24	264
26.	Cut section with machines	1	4x3=12	1.84	11.06	3.68	22.12
27.	Aspiration system around each machine in the cutting area	1	1x10=10	2	20	4	40
28.	Internal transport	-	-				
29.	Packing machine for plates FG		1x10=10	2	20	4	40
30.	Crane	1	1x8 = 8	4	32	4	32
31.	Quality assessment laboratory	1	1x3=3	0.5	1.5	0.5	1.5
32.	Repair workshop	1	40 80	1	40	1	80
33.	Living quarters	-	-				
34.	Control and computer regulations system	1	1.5	24	36	24	36
35.	Substation - facilities	1	-				
36.	Telephone connections - system - Director's office	1	1	24	24	24	24
37.	Freight elevator	1	1x5=5	1	5	2	10
38.	Stillages for drying and hardening	2	-				
39.	Composite mixture homogenizer	3	1x2.2=2.2	6	13.2	12	26.4
40.	Stretch table for products	4	3x1.5=4.5 1x3.5=3.5	3	24	6	48
41.	Matrices for products	8	-				

2.4. Labor costs and other expenses

Industrial-production staff and salary fund. Distribution of industrial-production staff by categories of shifts and productions.

List of required number of employees:

One superior of shift, automation and control engineer, higher education, male or female, works 3 shifts, 3 people.

Two equipment maintenance technicians - 1 mechanic and 1 electrician, secondary special education, men, working in 1 shift, 2 people.

Two technicians for work of all furnaces and equipment, technicians of silicate materials, secondary special education, men, work in 3 shifts, 6 people.

Three workers (for preparatory and final processing of the materials) and 1 forklift driver, work in 2 shifts, 8 people,

One technician controller, secondary special education "Silicate technology", man or woman, works 2 shifts, 2 people.

A total of 21 service personnel are needed for one industrial unit operating with 5 shaft furnaces and 1 rotary furnaces for granules for the first stage of commissioning of the plant. An additional 14 people are needed for the second stage of capacity implementation as follows:

Two equipment maintenance technicians - 1 mechanic and 1 electrician, secondary special education, men, working in 1 shift, 2 people.

Two technicians for work of 5 shaft furnaces and 1 rotary furnace for granules, technicians, secondary special education "Silicate technology", men, working in 3 shifts, 6 people.

Two the workers for preparatory and final processing of the materials, 1 employee (secondary special education "Silicate technology") and 1 forklift driver (secondary special education), men or women, work in 2 shifts, 4 people.

One technician controller, technicians, secondary special education "Silicate technology", man or woman, works 2 shifts 2 people.

A total of 35 staff are needed for the plant at full capacity.

Annual salary fund and accruals for social security and retraining and unemployment fund (calculation base)

The calculations of staff costs is provided the inclusion of additional remuneration for classes, night allowances and others, such as 40% of the normal inherent costs of materials for this type of industry and 20% harmful, including 35% for social security and 7% retraining and unemployment fund. A total of 21 service (Industrial-production) personnel are needed for the first stage of the commissioning facilities of the plant, with a total value of monthly salaries (from EUR 184,080 per year) or 23.01 EUR/cubic meter.

In the second stage from commissioning of the facilities for the engaged additional 14 employees, the same remuneration is provided as for the already working staff.

A total of 35 employees (industrial-production staff) are needed for the plant at full capacity, with a total annual salary of 306,800 EUR and a corresponding 19.18 EUR/cubic meter.

On this value for 1 cubic meter are included 35% for social security and 7% retraining and unemployment fund or a total of 42%. Then are included a total of 23.01 EUR /cubic meter for salaries in the first stage and 19.18 EUR/cubic meter for the second stage.

Depreciation deductions

Depreciation deductions are different for different capital investments:

For land and infrastructure - no deductions are provided

For a building - with 20 years term of deductions

The formulas by which we determine the depreciation and the residual value are:

$A = P/T$, where P is the value of the depreciable capital, and T is the depreciation time.

For 1 cubic meter we receive respectively for the first stage 2.8125 EUR / cubic meter and for the second stage 1.40625 EUR / cubic meter.

For the technological line - we use a formula with nonlinear dependence of residual value calculation.

$$P_{\text{res.}} = P(1 - \kappa)^T \text{ and } A = P - P_{\text{res.}}$$

$\kappa = 0,2$ and $T = 5$ years for this type of industry

For 1 cubic meter we add up the total depreciation for the ten years for the first and second stage, respectively, ie we receive 7.81 EUR / cubic meter for depreciation deductions for the first stage and for the second stage 6.23 EUR / cubic meter, which is average value for annual depreciation deductions. Real values are variables that will be reflected in the corresponding annual real costs.

For the second stage of operation of the technological line depreciation deductions are separated after the third year from the beginning of operation of the plant for FG.

2.5. Determining the full cost of produce and of the production and sales price

The values obtained are presented in Table 8. The thus formed factory price in two variants with minimum and maximum costs for the two stages of production shows the limits of the real factory price, which will probably be with average values within the obtained interval, ie. for the first stage for the manufacture of black foam glass 121.38 and for the production of colored foam glass 187,69 EUR / cubic meter, and for the second stage respectively 113.64 and 179.50 EUR / cubic meter.

Full cost of production, production cost by cost elements and analysis of basic costs

The table with the estimated cost shows that the elements for the formation of the full cost are from item 1 to item 6, respectively raw materials, energy costs, labor costs, other costs, depreciation deductions, additional costs, some of which are given as exact values, while others are defined as a percentage of the costs incurred so far, taken from the statistics for the respective type of production. The production price also includes the minimum planned profitability - 12% of the costs incurred for the full cost of production.

The following analysis of the main costs was performed:

- the costs of raw materials and other materials are constant;
- energy costs are also constant, unless the price of electricity increases above 0.15 EUR / kWh, which depends on government policy;
- labor costs are variable, on the one hand until the optimal composition of jobs is established, on the other hand, in order to have a lasting interest on the part of the staff, a progressive increase in wages is envisaged (for example by 5% per year, separately from inflation), which can be guaranteed from the profit, after repayment of loans used or in parallel with them;
- other costs, including transport of raw materials, maintenance and repair, which we define as 10% (of the costs incurred so far) and additional costs for wastage are variable in the direction of reduction, which is the responsibility of the plant management;
- depreciation deductions allocated to a separate fund are constantly decreasing for each subsequent one-year period. The full cost includes the average value for the first stage and the average value for the second stage of the production. The decision to use these funds is the responsibility of management;
- additional costs, including funds for advertising of manufactured products and funds for remuneration of administrative and managerial staff. These funds are necessary for the successful organization of production and realization of the final production. The main criteria in determining them is on the one hand that the funds provided do not significantly burden the cost of production, and on the other hand to contribute to the professional work and motivation of management. Of the 10% set aside, 2.5% is set allocated for advertising and the remaining 7.5% for the remuneration of the governing body (with a 5% increase in wages per year, apart from inflation).

For the 10-year planning period, the total amount of advertising is EUR 375,600, and the distribution by year is not evenly in order to promote the finished product at the beginning of its production.

Administrative staff is kept to a minimum. Funds are provided for the payment of the authors of the patent, fees for consultants in the planning and construction of the plant, other fees and maintaining minimum reserve.

The projected 12% minimum planned profitability (in a separate fund) determines the size of the minimum planned profit relative to the cost of production, and hence the average profitability relative to production funds, which is 10.6% for the first stage and 38.8% for the second stage from the work of the plant. This will help determine the exact value of the minimum selling price of the product.

Factors influencing full cost, production price and selling price

The factors influencing the full cost, production price and selling price of manufactured products are of two types - external and internal. The external ones are the normative documents, referring to the making of legally justified managerial decisions, and the internal ones leading to accumulation of maximum profit and optimally effective result from the production of this type of production in the created macroeconomic external environment, ie. the maximum possible selling price in order to realize the maximum profit and at the same time the sale of the entire produced quantity of production. A sale price of 130 EUR / cubic meter without VAT and 150 EUR / cubic meter with VAT is offered. Based on the presented values, a Business Plan has been prepared.

Capital investments and production funds

The capital investment is worth EUR 1.44 million for both stages.

Structure of capital investments and main production funds

Capital investments are divided into the following costs:

For land – 55,000 EUR

It is planned to purchase land with dimensions of 90x60 m = 5,400 sq.m, on which to build an industrial unit - a building with dimensions of 80 x 30 m = 2,400 sq.m.

Tab. 8 Full cost of produce and of the production and sales price.

No	Type of costs	Сума в EUR/m ³ foam glass at density 150 kg/m ³			
		Productivity			
		8,000 m ³ /year		16,000 m ³ /year	
		min	max	min	max
1.	Raw materials and other materials				
1.1	Main - waste glass	2.7	7.56	2,7	7,56
1.2	Auxiliary	0.0648	0.0648	0,0648	0,0648
1.2.1a	Foaming agent - soot (for comparison) - black foam glass	0.3	0.3	0,3	0,3
1.2.1b	Foaming agent - glycerin - black foam glass (technological additive - sodium silicate)	10.6	14.6	10,6	14,6
1.2.1c	Foaming agent - calcium carbonate - white foam glass	9.5	14.1	9,5	14,1
1.2.1d	Foaming agent - calcium carbonate and additional introduction of colorants - colored foam glass	84.75	89.1	84,75	89,1
1.2.2	Other auxiliary				
	Amount for point 1	3.0648	7.9248	3,0648	7,9248
	Average value	5.49 / 10,6 / 11.8 / 88.8		5.49 / 14,6 / 11.8 / 89.8	
2.	Energy costs for electricity 0,15 EUR/ kWh	27.23	39.30	26,73	38,85
	Average value	33.26		32.79	
	Amount for point 1 up to point 2	40.53	61.46	40,03	60,91
3.	Labor expenses				
3.1	Salary	16.21	16.21		
3.2	Accruals of 35% for social security	5.67	5.67		
3.3	Accruals of 7 % for unemployment and retraining	1.13	1.13		
	Amount for point 3	23.01	23.01	19,18	19,18
	Average value	9.95		7.535	
4.	Other expenses				
4.1	Transport of raw materials	0	3.00	0	3,00
	Amount from point 1 up to point 4.1	63.54	87.47	59,21	84,09
4.2	Maintenance and repair 10 % from the amount for point 1 up to point 4.1	6.35	8.75	5,92	8,41
	Amount from point 1 up to point 4.2	69.89	96.32	65,13	92,50
4.3	Losses from wastage 3 % from the amount for point 1 up to point 4.2	2.10	2.89	1,95	2,78
4.4	Packaging costs - pallets	4.6	5.6	4,6	5,6
	Amount for point 4	13.05	20.34	12,47	19,79
	Average value	16.69		16.13	
5.	Depreciation deductions A (calculated according to a special formula)				
5.1	For buildings	2.81	2.81	1,41	1,41
5.2	For technological line	7.81	7.81	6,23	6,23
	Amount for point 5	9.62	9.62	7,64	7,64
	Average value	9.62		7.64	
	Production cost price	48.56	88.46	44,07	76,55
	Amount for point 1 up to point 5.2	62.7	106.76	58,21	94,85
6.	Additional costs - 10 % from the amount for point 1 up to point 5 (advertising, salaries for administration and management)	8.62	11.44	7,93	10,85
	Average value	10.03		9.39	
	Full cost price – amount from point 1 up to point 6	94.83	125.87	87,25	119,37
7.	Profitability - 12 % from the amount for point 1 up to point 6	9.48	12.59	8,72	11,94
	Average value	11.04		10.33	
	Factory price – amount from point 1 up to point 7	104.31	138.46	95,97	131,31
	Average factory price for different types of FG at point 0.15 EUR/kWh	Black FG - soot - 104.38 Black FG – glycerin - (additive - sodium silicate) 121.38 White FG - CaCO ₃ - 110.69 Colored FG - CaCO ₃ and colorants - 187.69		95.89 113.64 102.50 179.50	

Note: Calculations are shown for the accepted foamer glycerin and sodium silicate. The other values are given for comparison.

For infrastructure EUR 80,000

For construction or building – 450,000 EUR

Building of the industrial unit with dimensions 80x30 m = 2,400 sq.m built-up area

For technological line - machines and equipment:

- first stage – 700,000 EUR.
- second stage – 155,000 EUR.

Working capital

Working capital is the sum of the value of the working funds and the circulation funds

The working funds are made up of the following components:

- raw materials and other materials expenses;
- energy costs;
- labor expenses;
- other costs - transport, maintenance and repair, wastage, packaging, etc.;

- additional costs - advertising, administration costs;

The working funds also includes work in progress and stock of raw materials and other materials in the amount of 15% for 1 year.

The circulation funds are formed by the following components:
-unrealized finished products - as quantity and value we accept finished products less than a unit of transport volume (eg 3/4 of the volume of a truck - TIR);

-costs for finished goods on road (full volume of the truck TIR) – 6,570 EUR.

Total value of working capital - is the sum of the above components increased by 20% for unforeseen additional costs

The minimum and maximum value of working capital shows the limits within which they can move. After analysis we accept 540,000 EUR.

Available main funds that will be used under the project

There are no main funds available at the time of project creation. After the realization of the project management form, opportunities will be sought to raise the planned funds.

Production funds

The production funds needed for the implementation of the project are the value of the technological line, respectively 700,000 EUR for the first stage of implementation and 155,000 EUR for the second stage, ie. a total of 855,000 EUR.

One-time costs

The one-off costs are for the purchase of land, construction of a building and infrastructure with a total value of 585,000 EUR.

The total value of the plant for the production of foam glass products is 2 million euros, increasing over time with changes of the inflation index and other external factors.

These data are included in the developed business plan.

NOTE: In the whole project the value of 1 EUR is equal to 2 BGN, limited by the Currency Board in the Republic of Bulgaria. The calculations are made until June 2021, and inflation is reflected proportionally in the changing economic situation.

3. Conclusions

Some financial parameters applicable in the preparation of a detailed Business plan for construction and operation of a plant for the production of various foam silicate products are presented: plates for sound and thermal insulation, colored decorative panels for building cladding, bulk foam granules, small and large structural composites elements (with different forms) with potential application in construction, industry, energy, shipbuilding, etc.

The preliminary calculations for the necessary funds for raw materials, other material, land, appropriate technical equipment, electricity, labor, advertising and other costs for the project are considered. Based on the presented data, the estimated total investment value (for the construction of the plant) in the amount of 2 million EUR has been determined.

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Economic Comparison of the Two Proposed Wind Farms in Mamaj, Albania

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Abstract: The study addresses to an economic comparison of two proposed wind farms in the same area in Mamaj, Albania, respectively 10.8 MW and 12.6 MW. The 12.6 MW wind farm proposed is predicted to produce 34 GWh energy, with a capacity factor of 30.8%, while the 10.8 MW wind farm is predicted to produce 30.4 GWh, with a capacity factor of 32%. For the 12.6 MW wind farm since there is a higher installed power, is expected to produce more energy, but referring that they will be built in same area, the wake losses will indicate in overall efficiency of the wind farm. The wake losses calculated for the 10.8 MW wind farm are 0.98%, meantime for the 12.6 MW wind farm wake losses is calculated 2.58%, means that the overall efficiency of the 10.8 MW wind farms is higher. For the economic evaluation RETScreen Expert software is used. With a discount rate of 7%, the benefit-cost ratio is 2.9 and simple payback period 7.6 years for 10.8MW wind farm, and for the 12.6 MW the benefit-cost ratio is calculated 2.6, with a simple payback year of 8 years.

Keywords: WIND ENERGY, WAsP, BENEFIT-COST RATIO, DISCOUNT RATE, NET PRESENT VALUE, SIMPLE PAYBACK PERIOD, RETSCREEN EXPERT.

1. Introduction

Power generation from renewables is the only major source of energy that has continued to grow, and this resilience sets the tone for the next decade and beyond [1]. Renewables are becoming more and more competitive in energy landscape [2]. The current crisis in Ukraine clearly showed how weak and vulnerable is the economy of countries with an energy system deeply intertwined with fossil fuels.

There is a need for strong national strategies to phase out fossil fuels and in parallel increase the production of renewable energy and use that energy much more efficiently than we do today [3].

Some 80% of the global population lives in countries that are net energy importers. With the abundance of renewable potential yet to be harnessed, this percentage can be dramatically reduced [4]. Often, renewable energy is thought of as a novel technology, although its origins date back thousands of years [5, 6]. Today, with a rapid technological development that focuses not only on economic efficiency but also on mitigating environmental repercussions, wind energy as well as solar power as being used in increasingly cost-efficient ways, making renewables a crucial power source.

Wind and sunshine don't cost anything, and nations that embrace renewables as the backbone of their energy system will be protected from the price swings of volatile fossil fuels [7].

According to Director-General of International Renewable Energy Agency, the global shift to renewables is underway. 2021 was a strong year for the energy transition – the world added almost 257 Gigawatts (GW) of renewables contributing to an unprecedented 81% of global power additions [8]. 2020 marked a record year for new global installations of wind energy with 93 GW. 2021 was also a big year for wind installations with a total of 94 GW of wind installed around the world. This demonstrates the incredible resilience and an upward trajectory of the global wind industry. However, within this decade, wind installations need to increase almost 4 times compared to 2021 in order to meet the goal of the Paris Agreement to limit the increase of global average temperature to 1.5°C above pre-industrial levels (see Figure 1) [7, 9, 10].

Europe installed 17.4 GW of new wind energy capacity in 2021. This was 18% more than 2020. Onshore wind made 81% of the new wind installations with 14 GW. Europe now has 236 GW of wind capacity generating 437 TWh of electricity in 2021, covering 15% of the Europe's electricity demand [11]. Although 2021 is a record year for new wind installations, the rate of growth is still not

sufficient for Europe to reach its 2030 energy and climate goals [8, 11].

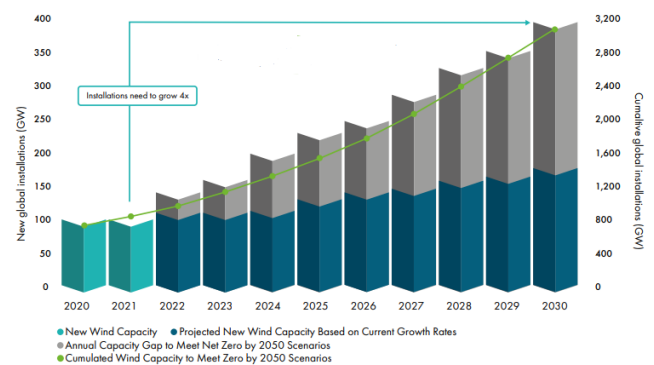


Fig. 1 The annual wind energy installation needs to scale up by four times in this decade to stay on track for a net zero/1.5°C pathway. Source: GWEC [7]

The Albanian government has set national energy targets in order to further integrate the country into the European energy infrastructure. Renewable energies are projected to be 42% of the total energy consumption by 2030. Consistent with the Paris Agreement, in 2015 the Albanian government commits to reducing GHG emissions by 11.5% by 2030, compared with the baseline scenario of the year 2016. [12]. Although Albania's energy mix already features one of the highest shares of renewables in the region due to the extensive installed hydropower capacity, diversifying the electricity mix including solar and wind power, can contribute to a secure, stable, affordable national energy supply. Furthermore, this would contribute to the reduction of imports in the energy sector. The hydric sources are mostly concentrated in the northern region of the country, while the highest number of consumers are based in the western part and around 35% of theirs are in the eastern part of the country. Therefore, a shift towards non-hydro-based renewable generation close to demand centers would be advantageous in continued power sector development and in decreasing of electricity losses [12, 13]. Since the introduction of the solar and wind FiT support, Albania has made progress towards the diversification of electricity production but only for solar power.

According to the energy balance of 2021, no kWh of electricity has been produced through wind power yet [14]. The applications for the construction of the wind plants up to 3 MW according NANR are still being evaluated for their wind potential. Each successful bidder of projects with a minimum capacity of 30 MW and a maximum capacity of 75 MW, through a tender process according to the law, will sign a 15-year Power Purchase

Agreement for the sale of 100% of the electricity generated through the Contract for Difference support mechanism [15]. On June 12th 2018, the Council of Ministers of Albania passed a decision on wind farm projects over 3MW, specifying that support will be given through an open, non-discriminatory, transparent and competitive process for the projects that offer optimal conditions in terms of energy cost, level of technology and building plan. The competitive process will result in a feed-in tariff which will remain unchanged for a period of time of up to 15 years. This tariff will not be higher than 76 €/MWh which is the amount that ERE has approved for this technology.

The success of wind power projects relies on finding the specific area with wind potential, the choice of the most effective turbine, and the site-planning of the turbines as to have the least wake losses. The aim is to generate the most electrical energy with the least wake losses to ensure a higher capacity factor for the proposed wind farm.

Wind farm projects require from the beginning a large investment of capital. The capital cost of wind energy project is dominated by the cost of the wind turbines including there the cost of the tower and installation. Often it is known as CAPEX (Capital Expenditures) and this can be between 64% and as much as 84% of the total installed cost for onshore wind projects [16]. Thus, a wind farm is capital-intensive compared to conventional fossil fuel fired technologies such as a natural gas power plant, where as much as 40-70% of costs are related to fuel and O&M [17]. Investors' decision to build a wind farm relies on a detailed economic analysis. This study is considering two wind farm projects, 10.8 MW and 12.6 MW respectively, proposed in the same area in Mamaj, Albania. WAsP software is used to do the technical evaluation. This study shows the importance of the economic analysis in selecting the best project. RETScreen Expert is used to do the economic evaluation.

2. Materials

The two proposed wind farms in our study are respectively 10.8 MW and 12.6 MW in the same area in Mamaj, north of Tepelenë, Albania. Both the map of potential areas for wind energy in Albania, from Balcan Wind Atlas (50m above ground level) and the map of Albania's annual average wind speeds at 100m hub-height from Global Wind Atlas 1.0, identify the area proposed as one of the estimated sites for wind potential (see in Figure 2, 3).

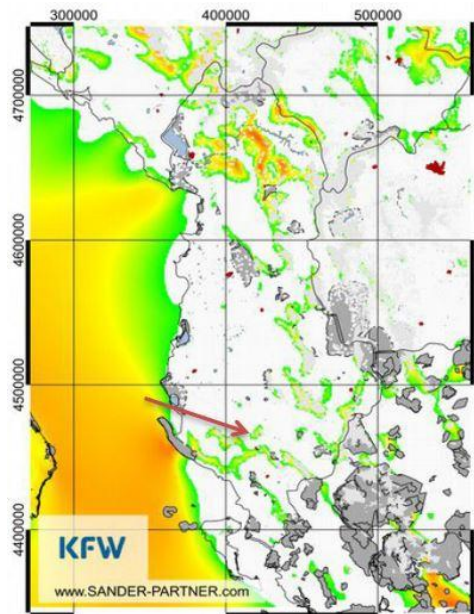


Fig. 2 The map of potential areas for wind energy with good wind conditions, that respect natural reserves. The area of the proposed wind projects is an estimated site. Source: Balkan Wind Atlas, KfW sander@sander-partner.com

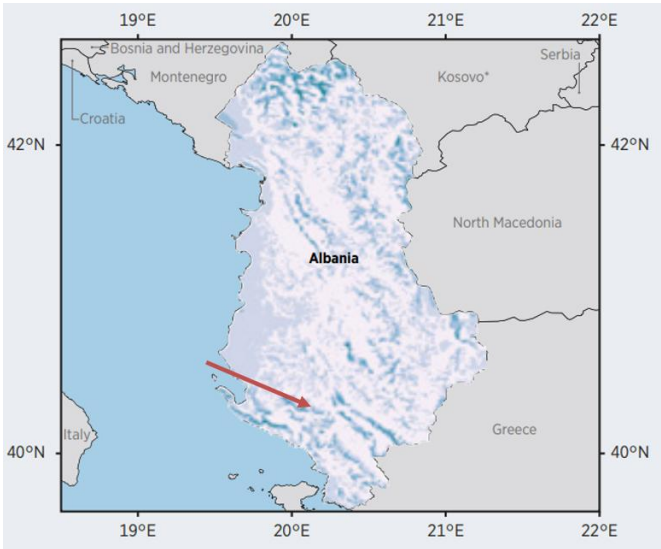


Fig. 3 The map of potential areas for wind energy according of Global Wind Atlas 1.0. Mamaj, the proposed wind farm project's site as one of the estimated. Source:[13]

The meteorological data such as air temperature, atmospheric pressure, wind direction and wind speed were acquired through anemometers installed in two separate towers with a height of 60m each and in a distance about 800m from each other at the exact location for 456 days. In a previous study, wind resource assessment of the site based on the map of wind potential distribution (resource grid) generated by WAsP program, showed that the mean wind speed was found to be 5.64 m/s on the hill and the annual mean wind power density of 304 W/m², in 50m height above ground level defining this site to correspond to the wind power class 3 [18, 19]. This wind power class is appreciated for building a wind farm.

Wind farm prediction with WAsP software demonstrated that maximum Annual Energy Production with minimum wake losses was achieved in case of Vestas V100/1800 wind turbines with arrangement of 6 and 7 wind turbines respectively as in Figure 4 and Figure 5.

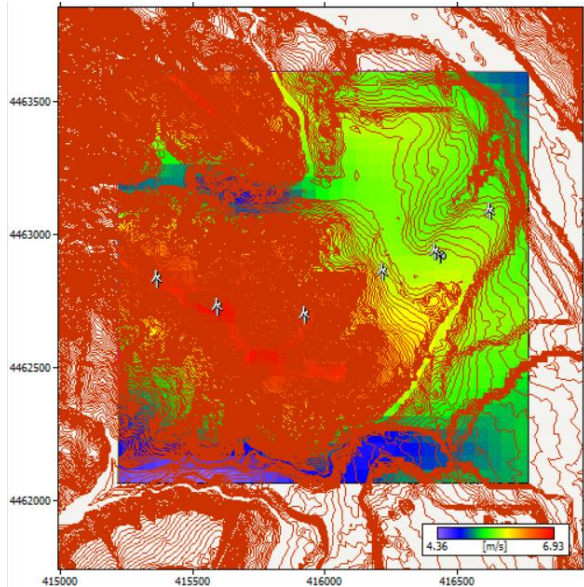


Fig. 4 Mamaj Wind Farm Layout Design of 10.8 MW.

Total net AEP [GWh]	30.4
Proportional wake losses [%]	0.98
Capacity factor	32%
Efficiency	99.02%

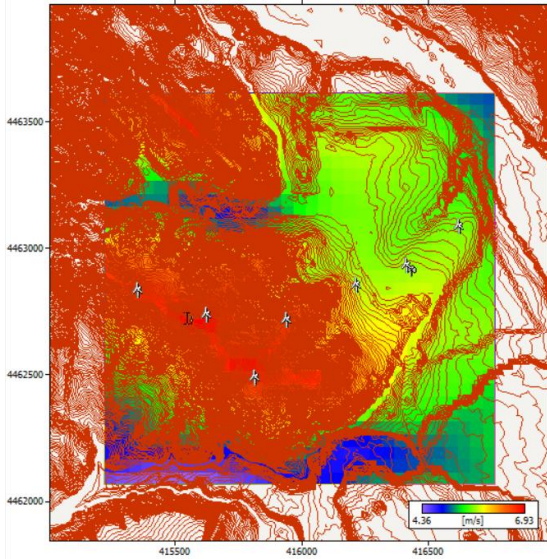


Fig. 5 Mamaj Wind Farm Layout Design of 12.6 MW.

Total net AEP [GWh]	34
Proportional wake losses [%]	2.58
Capacity factor	30.8%
Efficiency	97.42%

RETScreen Expert is used to do the economic evaluation. In both cases the debt ratio is considered 70%, debt term 15 years, with a 3-year debt interest rate. Discount rate is considered 7% and the inflation rate 2.5%. The electricity generated by the wind farms is assumed to be delivered with a sell price of 76 €/MWh.

In two previous research studies [20, 21] is provided a sensitivity economic analysis for helping the decision-makers to understand the importance of the impact of financial feasibility indicators in relation to key technical parameters in wind farm projects. In this study an “Relative analysis” to define the best of the proposed wind farms in terms of costs and benefits is used.

The benefit-cost ratio, (B-C), is an expression of the relative profitability of the project (equation 1). It is calculated as a ratio of the present value of annual revenues (income and/or savings) fewer annual costs to the project equity:

$$B - C = \frac{NPV + (1 - f_d)C}{(1 - f_d)C} \quad (1)$$

where: C is the total initial cost of the project, NPV is Net Present Value (the value of all future cash flows, discounted at the discount rate, in today's currency), and f_d is the debt ratio. The higher the ratio, means the more the euro savings realized per euro of investment.

The net annual returns include the revenue from selling the electricity produced from the wind farm during its active operation period. They are dependent on the wind farm capacity factor, as well as the price of electricity is being sold at, which in turn are dependent on the climate of the proposed area of the project, the type of wind turbines and layout design of wind farm, as well as on O&M's annual costs.

We estimated the predicted revenue during a project lifetime of 25 years. However, due to multiple factors, one euro earned or spent tomorrow is not worth the same as one euro today. This concept leads to a technique of economic appraisal known as discounted cash flow (DCF) analysis.

Therefore, to bring back to the present the future net incomes stream that flow every year from the project, we have to know, the discount rate r . The level of the discount rate depends on the risk of the investment [22].

The simple payback SP is the number of years it takes for the cash flow (excluding debt payments) to equal the total investment (which is equal to the sum of the debt and equity) (equation 2):

$$SP = \frac{C - IG}{(C_{ener} + C_{capa} + C_{RE} + C_{GHG}) - (C_{O\&M} + C_{fuel})} \quad (2)$$

where: IG is the value of incentives and grants; C_{ener} is the annual energy savings or income; C_{capa} is the annual capacity savings or income; C_{RE} is the annual renewable energy (RE) production credit income; C_{GHG} is the GHG reduction income; $C_{O\&M}$ is the yearly operation and maintenance costs incurred by the clean energy project and C_{fuel} is the annual cost of fuel or electricity.

The year-to-positive cash flow (also known as Equity payback) N_{PCF} is the first year that the cumulative cash flows for the project are positive. It is calculated by solving the equation (3) for N_{PCF} :

$$0 = \sum_{n=0}^{N_{PCF}} \tilde{C}_n \quad (3)$$

where $\tilde{C}_n$ is the after-tax cash flow in year n .

The equity payback represents the length of time that it takes for the owner of a facility to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback is a better time indicator of the project merits than the simple payback.

3. Results

For the Mamaj area two wind farms are proposed, respectively 10.8 MW and 12.6 MW. To do technical evaluation WAsP software is used. The 10.8MW wind farms consists in the installation of 6 Vestas V100-1.8MW wind turbines, with a power capacity of 1.8 MW for each wind turbine. The projected wind farm is calculated to export 30.4GWh electricity yearly, with a capacity factor equal to 32% and with an overall efficiency of the farm that is predicted to be approximately 99%, because of wake losses which are equal to 0.98% of the overall efficiency of the wind farm. While, the 12.6 MW wind farm consists in 7 Vestas wind turbine, with the same power capacity installed for each wind turbine, 1.8MW. Wind farm is calculated to export 34 GWh electricity yearly, with a wind farm capacity factor of 30.8% because of the wake losses calculated approximately 2.58% hence, the overall efficiency of the windfarm will be approximately 97.42%.

To do the economic evaluation RETScreen Expert will be used. The initial infilled parameters values for both 10,8MW and 12,6MW wind farms are in Table 1. In both cases the debt ratio is considered 70%, debt term 15 years, with a 3-year debt interest rate, since is a high initial project cost. Discount rate is considered 7%, as the normal interval varies from 5% to 11%.

Table 1. Infill parameters values for the both 10.8MW and 12.6MW wind farms.

Components	Value	Unit
Inflation rate	2.5	%
Discount rate	7	%
Project life	25	yr
Debt ratio	70	%
Debt interest rate	3	%
Debt term	15	yr

For the wind farm 10.8 MW, the equity payback is calculated 4.2 years and simple payback 7.6 years, with a cumulative cash flow of 22.44 M€, and a net yearly cash flow-first year equal to 0.972 M€ (see in Figure 6).

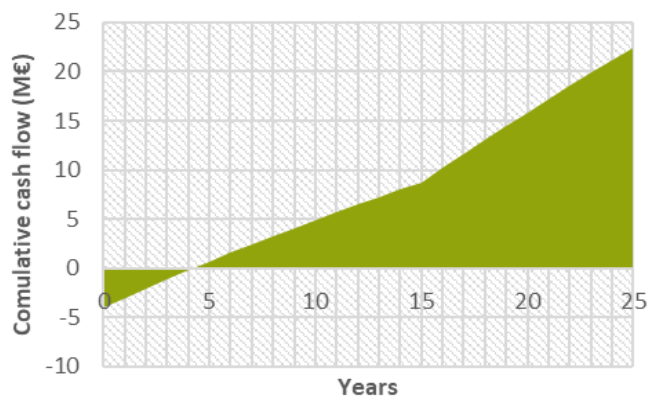


Fig. 6. Payback period and cumulative cash flow for the 10.8MW wind farm in years

From the RETScreen simulation is seen that for the 10.8MW the NVP (Net Present Value – the difference between the inflows and outflows cash of project) is equal to 7.461 M€, with a benefit cost ratio of 2.9. The LCOE for this project is calculated 0.055 €/kWh, Table 2.

Table 2. Results for 10.8MW wind farm.

Components	Value	Unit
Simple payback	7.6	yr
NVP	7,461,796	€
Benefit-cost ratio	2.9	-
Energy production cost	0.055	€/kWh

Regarding the 12.6 MW wind farm, with an initial cost of 15.38 M€, the cumulative cash flow will be 23.52 M€, with a simple payback period of 8 years and equity payback equal to 4.7 years, as it is shown in Figure 7.

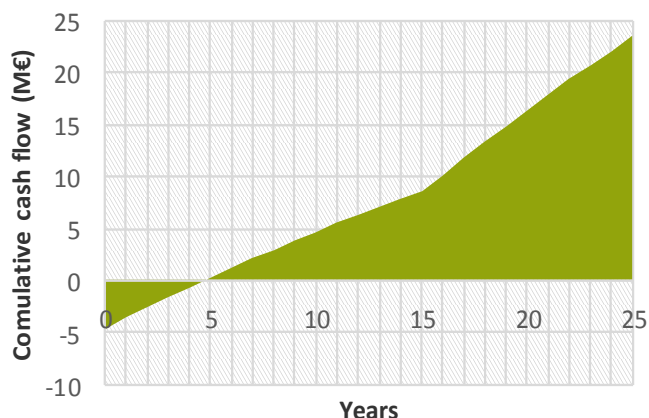


Fig. 7. Payback period and cumulative cash flow for the 12.6MW wind farm

Results shows that the NVP for 12.6 MW is equal to 7.46 M€, with a benefit cost ratio of 2.6. Energy production cost or LCOE in this case is 0.057 €/kWh, higher than the 10.8 MW wind farm (Table 3).

Table 3. Results for 12.6MW wind farm.

Components	Value	Unit
Simple payback	8	yr
NVP	7,461,160	€
Benefit-cost ratio	2.6	-
Energy production cost	0.057	€/kWh

3. Conclusions

This study consists in the economic evaluation of two wind farms respectively 10.8MW and 12.6MW, which will be placed in the same area. The difference between two wind farms is the number of wind turbines. For the 10.8MW wind farm will be used 6 Vestas wind turbines, with a power capacity of 1.8 MW of each turbine, while for the 12.6 MW wind farm will be used 7 same wind turbines. Since the turbines will be placed in the same area the wake losses from the array of the wind turbines, for the 12.6MW wind farm the losses will be higher than the 10.8 MW wind farm, respectively 2.58% and 0.98% of the overall efficiency of the wind farms, which indirectly indicates in the yearly electricity generation from the wind farm. Net electricity exported to grid including wake losses will be 34 GWh for the 12.6 MW wind farm and 30.4GWh for the 10.8 MW.

For the economic evaluation RETScreen software is used. As it seen from the comparison of the results from the two wind farms, with a discount rate 7%, the benefit-cost ratio is 2.9 for the 10.8 MW wind farm and 2.6 for the 12.6 MW (Table 4).

Table 4. Results for 10.8MW and 12.6MW wind farm.

Cases	Simple Payback [yr]	Benefit-cost ratio	Energy production Cost [€/kWh]
Wind farm 10.8MW	7.6	2.9	0.055
Wind farm 12.6MW	8	2.6	0.057

Also, the simple payback period is lower for the 10.8MW farm, equal to 7.6 years, with 0.4 years less than the other wind farm. Hence, the energy cost is lower respectively 0.055 €/kWh and 0.057 €/kWh, (Table 2, 3). As seen from the comparison of the results, the wind farm 10.8 MW is more cost effective, than the 12.6 MW wind farm, due to higher wake losses, which decreases the overall efficiency of the wind farm to 97.42%.

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Friction stir welding of dissimilar materials based on aluminum alloys

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Abstract: The paper focuses on the application of friction stir welding (FSW) technology for welding of unequal materials based on aluminum alloys. Joints were made from AW 5083 and AW 6082 materials using FSW technology at different weld speed values. The joints were analyzed metallographically, the hardness of the materials was tested across the cross section of the joint and the strength of the joint was tested by destructive static tensile test. At the lowest weld speed, the materials were not perfectly mixed, there was a macroscopically visible gap at the joint location, which was reflected in the lack of joint strength. At the medium and highest weld speed values, a joint with mechanical properties comparable to those of the base material was formed. Metallographically, the bond between the materials was free of any internal defects.

Keywords: FRICTION STIR WELDING, ALUMINUM ALLOYS, STATIC TENSILE TEST, HARDNESS, MICROSTRUCTURE

1. Introduction

The challenges in metal joining technology are becoming more intense across the industry. Along with the introduction of new materials for use in industry, there is also the task of researching and innovating, or developing new technologies for processing these materials. However, when applying new joining methods, it is always necessary to guarantee the quality and strength of the products.

Trends in car development are leading to an increase in the share of light alloys in cars. The application of aluminum and magnesium alloys in the automotive industry results in more efficient and economical operation of automobiles, while maintaining or improving the required properties. Friction stir welding (FSW) technology in automotive serial assembly-line production was first implemented in 2012 [1]. Satisfactory results of welding aluminum-steel alloys to the load-bearing parts of components show improved driving characteristics as well as shorter car production time.

Welding tools and optimal process parameters are important elements in FSW welding. By choosing the material and the geometric shape of the tool together with the combination of configuring the process parameters, welding of materials according to the valid standards can be ensured. The tool consists of two parts: pin and shoulder. The FSW welding process consists in that, the rotating tool pin is gradually pressed into the components or blanks to be weld, where the entire tool then performs a rectilinear movement along the welding gap between the components. During this movement, the materials are mechanically mixed by the action of the tool without external heating. The increased process temperature is due to internal friction in the materials. The tool can move clockwise or counterclockwise [2-3].

The practical part of the article is focused on the assessment of mechanical properties and microstructure of joints of two aluminum alloys performed by FSW technology. The microstructure of the joints was assessed by metallography and mechanical properties of the joints by hardness measurement and static tensile test [4-5].

2. Materials and methods

FSW welding of unequal materials was performed between AW5083 (AlMg4.5Mn0.7) and AW6082 (AlSi1MgMn) alloys. The welded plates had a constant thickness of 10 mm. The chemical composition of welded alloys is given in Tab.1.

Table 1: Chemical composition of alloys in wt.%, Al - balance

alloy	Si	Fe	Cu	Mn	Cr	Ni	Zn	Ti	Mg
5083	0.075	0.14	0.033	0.60	0.068	0.002	0.33	0.053	4.35
6082	0.85	0.32	0.01	0.62	0.18	-	0.12	0.08	0.75

The mechanical properties of welded alloys are given in Tab.2.

Table 2: Mechanical properties of welded alloys

	$R_{p0.2}$ [MPa]	R_m [MPa]	A_5 [%]
AW 5083	237	330	16,3
AW 6082	185	243	11,5

The dimensions of the test plates machined for welding were: 200×250×10 mm.

Aluminum alloy AW 5083 contains magnesium and manganese as main alloying elements. Its advantage is high strength and hardness and therefore it is easy to machine by drilling, turning, milling. It has very good machinability, resistance to corrosion caused by seawater. It can be used in mechanical engineering for welded structures and foaming molds, for shipbuilding, tools and vehicle production.

Aluminum alloy AW 6082 contains silicon, magnesium and manganese as main alloying elements. Due to the higher addition of silicon and manganese, it has good strength and hardness and, again, is therefore easy to machine by drilling, turning and milling. It has good corrosion resistance, outstanding thermal conductivity and good anodizing. It is used in mechanical engineering for welded structures, for transport technology building and shipbuilding.

The welding tool had a simple conical shape. It was made of tool steel X40CrMoV5-1. Shoulder diameter was $\varnothing 25$ mm, pin diameter $\varnothing 12$ mm, pin length 9.7 mm with 10° taper, Fig. 1.

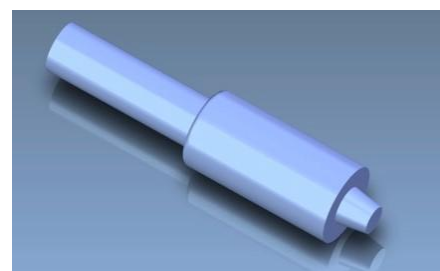


Fig. 1 Welding tool in 3D view

Welding parameters are given in Tab.3. When testing the parameters, only the tool feed speed (welding speed) changed from 100 mm/min to 60 mm/min. The tool rotation speed and angle of inclination of the tool were kept constant.

Table 3: Sample welding parameters

Sample number	Tool rotation speed (rpm)	Welding speed (mm/min)	Tool inclination ($^\circ$)
1	600	100	1.5° to 4.5°
2	600	60	1.5° to 4.5°
3	600	80	1.5° to 4.5°

The following tests were performed on the welds:

1. Metallographic analysis of welds according to ISO 42 0461
2. Microhardness testing of welded joints according to ISO 9015-2. The hardness was measured by the Vickers method at a load of 200 g. Microhardness was evaluated in the base materials (BM), the heat affected zone (HAZ) and in the weld metal (WM). The microhardness of the test specimens was evaluated on electropolished metallographic sections. A Shimadzu HMV 2 hardness tester was used for this test.
3. Transverse tensile test according to ISO 4136. A universal tensile test machine Instron 8806 was used. 3 samples from each welded plate were tested in the experiment.

3. Results

The appearance of the welds is shown in Fig. 2.

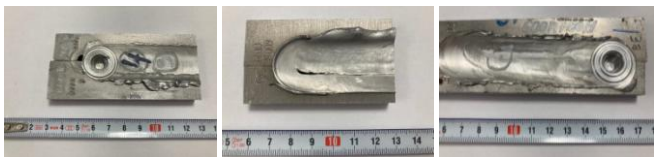


Fig. 2 Sample No.1 (left), sample No.2 (middle), sample No.3 (right)

From Fig. 2, it can be seen a gap on sample No. 2 after welding, which indicates unmixed materials.

The hardness of the joints across all weld areas is given in Tab.4.

Table 4: Microhardness of welds HV0.2

Sample	BM	HAZ	WM	HAZ	BM
1-1	83	81	85	80	82
1-2	82	82	83	82	82
1-3	83	81	84	81	83
2-1	-	-	-	-	-
2-2	-	-	-	-	-
2-3	-	-	-	-	-
3-1	82	80	84	81	82
3-2	81	80	85	81	83
3-3	82	82	84	82	83

BM – base material, HAZ – heat affected zone, WM – weld metal

In sample No. 2, the microhardness measurement was not performed due to the presence of cavity in the weld metal. Based on the measured values, it can be stated that the microhardness values of the welded joints varied within the range of 80 to 85 HV0.2. HAZ showed minimum average values of 81 HV0.2. The base materials had an average microhardness value of 82 HV0.2. The maximum value of microhardness was shown by the weld metal, namely 84HV0.2. Differences in joint hardness in different joint areas are negligible. This indicates a minimal temperature influence of the material during welding

From a macroscopic point of view, a small volume of material can be observed on the specimens squeezed out of the weld site above the level of the material. The main causes of these defects may be excessive immersion of the welding tool in the weldment. Such a weld joint may have an unacceptable appearance, requiring additional mechanical machining of the surface, but nevertheless

the strength properties may be satisfactory.

The results of the tensile test of the welded joint are given in Tab.5. The results are the average of 3 measurements.

Table 5: Tensile test results

Sample	R _{p0.2} [MPa]	R _m [MPa]	A ₅ [%]	Location of failure
1	192	282	14	WM
2	66	77	5.6	WM
3	198	285	14	WM

Based on the tensile tests of the welded joint in the transverse direction, it can be stated that the minimum values of tensile strength reached the samples made of plate No. 2. The reason was poor weld quality, the presence of internal defects, insufficient mixing and joining of materials. Samples made from plates No. 1 and 3, where the welding speed was 100 and 800 mm/min respectively, showed the highest average values. Destruction of all samples occurred in the weld metal.

Sample No.1: Figs. 3 - 5 show metallography analysis (macroscopic and microscopic view) of sample No.1.

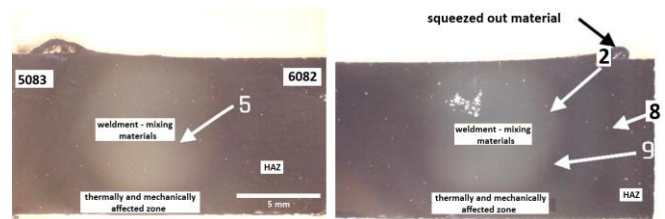


Fig. 3 Sample No.1 macroscopic view, indication of positions for microscopic observation

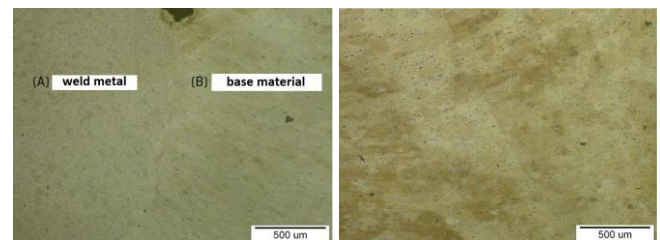


Fig. 4 Microscopic view, position 2 (left) and position 5 (right)

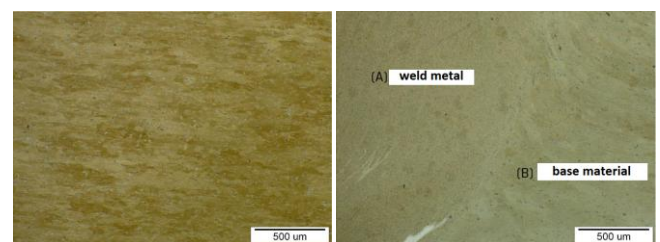


Fig. 5 Microscopic view, position 8 (left) and position 9 (right)

From Fig. 3-5 is clear, that both materials were thoroughly mixed during welding. The boundary between the base material and the mixed area cannot be distinguished microscopically.

Sample No.2: Figs. 6 - 8 show metallography analysis (macroscopic and microscopic view) of sample No.2.

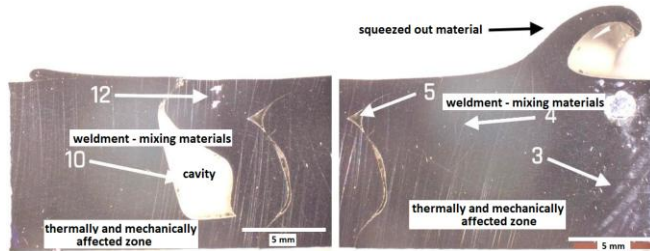


Fig. 6 Sample No.2 macroscopic view, indication of positions for microscopic observation

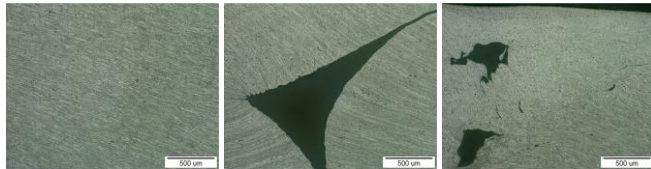


Fig. 7 Microscopic view, position 4 (left), position 5 (in the middle) and position 12 (right).

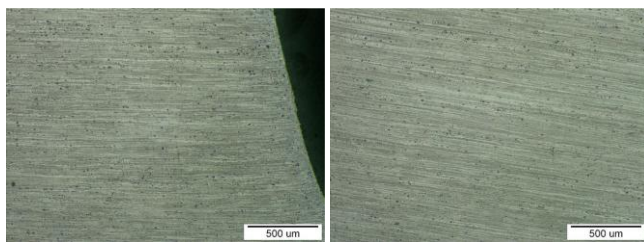


Fig. 8 Microscopic view, position 10 (left) and position 3 (right)

When observed with the naked eye of sample No.2, it is possible to see a surface defect in the weld. The surface gap along the weld line was probably due to the low welding speed. Microscopic view of sample No.2 in Figure 7 (positions 12 and 5) shows unmixed materials in the weld metal.

Sample No.3: Figs. 9 - 11 show metallography analysis (macroscopic and microscopic view) of sample No.3.

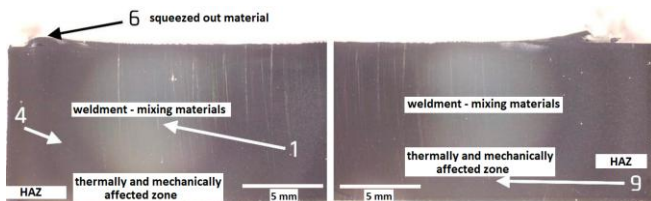


Fig. 9 Sample No.3 macroscopic view, indication of positions for microscopic observation

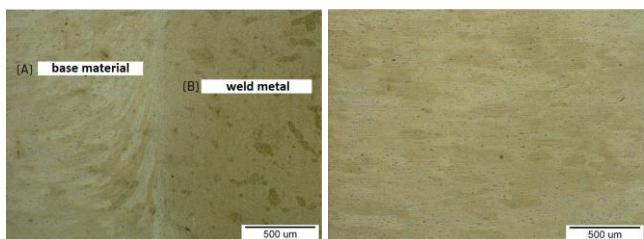


Fig. 10 Microscopic view, position 1 (left) and position 4 (right)

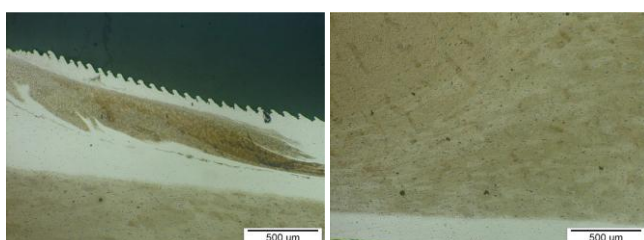


Fig. 11 Microscopic view, position 6 (left) and position 9 (right)

There is no microscopically distinguishable interface between the base materials and the mixing zone, there is a perfect mixing of the welded materials without the presence of defects and cavities, positions 1, 4 and 9, Figs. 10, 11. The surface of the squeezed material (position 12) has a sawtooth character indicating a gradual uniform plastic deformation of the material surface during welding.

4. Conclusion

Different microhardness and tensile test results could be observed on the test specimens made from aluminum alloys AW5083 and AW6082, which had different process parameters. The increased hardness above the weld zone is directly influenced by grain refinement. In the case of specimen 2, the presence of defects on the weld surface could already be observed after visual inspection. The microstructure of the individual materials was similar for all the samples examined. The maximum average values of the mechanical properties were exhibited by sample 3, where the welding speed was at the middle values of all the examined samples. Recrystallization of the material occurred in the core of the weld for all specimens. The material that was at a greater distance was only thermally affected, without recrystallization. Based on the set of metallographic images, it can be argued that the microstructure in the weld is not homogeneous.

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Innovative method for repair of reinforced concrete water facilities by “wet” shotcreting

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Abstract: The report presents the different stages of development and implementation of two similar innovative technical solutions for repair and restoration of defected reinforced-concrete constructions of existing swimming pool and artificial lake using the methods of “wet” shotcreting. In the first case, the object of renovation is a seriously defected outdoor mineral pool of a prestigious hotel in the town of Hissarya. Given the significant leaks of water from the pool in the surrounding area over the years, a specialized technical inspection was initially conducted to determine the causes of defects in the main load-bearing monolithic steel-reinforced concrete construction - walls and bottom slab. An innovative technical solution has been proposed to restore the operational suitability of the pool, based on the possibility of using the existing load-bearing structure as external formwork for a new built-in load-bearing structure of the facility. The proposed solution envisages jointless thickening of the existing walls through additional reinforcement and concrete laying of new high-tech sprayed concrete. The bottom of the pool is being renovated by additional new layer of a hybrid fiber-reinforced jointless concrete slab and machine power-floated of the finishing surface. A composition of high-tech concrete with the participation of an internal crystallization chemical admixture and shrinkage-compensating one is proposed. A similar solution has been applied for the repair and restoration of the walls and bottom of an artificial lake in West Park, Sofia. Implementation of the project creates a unique art vision of the lake, the rock garden and the surrounding park space. This pilot implementation creates objective preconditions for expanding the range of innovative concrete structural systems, which, in addition to specific functions, are also applicable as opportunities for aestheticizing the urban and park environment.

Keywords: WATER FACILITIES, HYBRID FIBER-REINFORCED CONCRETE, INTERNAL CRYSTALLIZATION CHEMICAL ADMIXTURE AND SHRINKAGE-COMPENSATING ADMIXTURE, CONCRETE JOINT-FREE SLAB, SHOTCRETING

1. Introduction

It is well-known that shotcreting is a special building technology patented in 1911 by Dr. Carl Akeley, curator at the Field Columbian Museum in Chicago. The system enables one to deposit a cement-sand mix or concrete on various surfaces via high pressure and without shuttering (forming) using a special equipment- a shotcreting machine and air compressor. In fact, this is a method of conveying concrete or mortar through a hose and pneumatically projecting it at high velocity onto a surface without additional compaction. This predetermines a number of essential advantages - high density and strength, low permeability (high water impermeability), high corrosion resistance, minimized shrinkage etc.

Two basic methods of shotcreting exist – “dry” and “wet” method.

A mix with cement and added sand, fraction (0-4 mm), prepared “dry” and deposited on a surface is known as “dry” shotcrete while that with aggregate fraction up to 20 mm - as “dry” sprayed concrete. Water is separately supplied through another hose.

The system for “wet” shotcreting employs special machines and supposes deposition of a specific concrete “wet” mix design. Its preparation is centralized at concrete batching plant and its consistency is précised (the usual water/cement ratio is below 0,45). Wet” shotcreting is based on work with certified concrete mixes, being “intentionally” designed and industrially prepared. Their optimization is flexible to meet the specific technical requirements and conditions of exploitation. A potential of multi-factor optimization of the mix composition also exists. It consists in the variability of selection of cement, aggregates, special chemical admixture with high-range water reduction effect, special in-depth crystallizers and polymer modifiers, fiber-reinforcement consisting of various types of fibers etc. The basic advantages of the method are its increased productivity, possibilities of a single-stage deposition of a thick layer, minimal operational subjectivity and increased ecology-friendliness of mix homogenization and deposition. A disadvantage of the method is the impossibility of its application if there is no certified concrete plant nearby.

Summarizing all advantages and possible specific building applications of “wet” shotcreting it could be concluded that new innovative methods for repair of damaged reinforced concrete water facilities (as swimming and spa-pools, artificial lakes etc.) by “wet” shotcreting is very attractive one [1].

It should be preliminary added that most of these types of reinforced-concrete structures are with special geometrical shapes -

oval, elliptical, variable sizes in plan and height. That’s the reason to estimate all conventional formworks available as unappropriated for using ones. Logically observe, in such specific cases, damage repairing by shotcreting is should be estimated as most preferable one.

In this connection below are discussed two specific innovative technical solutions for repairing works in such facilities - spa outdoor swimming pool in a prestigious hotel in Hissarya, and an artificial lake in West Park in Sofia.

2. Spa-outdoor swimming pool

2.1. Pool characteristics

The pool complex was designed and built in 2003 and contain 3 closely connected areas located in different design levels – main pool, children pool and water bar. Total area of the pool is around 1500 m² - (Photos 1 and 2). Main load-bearing structure is monolithic reinforced concrete - walls and bottom slab with plumbing channels located in it. From the provided reinforcement plans it is seen that the steel reinforcement for the bottom slab and walls of the pool should be double (Ø12 every 15 cm in both directions). The designed concrete is intended to have a compressive strength class C12/15 (water tightness 0,4). The thickness of the walls and bottom of the pool is 20 cm.

During the nearly 20 years of operation in the construction of the pool, many defects were observed (mainly visible structural cracks and damage to the ceramic cladding on the walls and bottom slab), which led to abundant water leakage and flooding of the surrounding area.

In order to establish the causes of such defects, a detailed constructive inspection was initially carried out.

In the scope of the constructive survey performed are included:

- Study of the available technical documentation;
- Technical inspection on site, verification of the geometry according to the provided geodesy survey, establishment of dimensions of characteristic sections of the structural elements, establishment of local defects;
- Cracks width measuring – Photos 3 and 4;
- Determining the compressive strength of concrete by testing test specimens (cores) cut from the structure of the site and checking their compliance with standard requirements – Photos 5, 6 and 8;
- Determining the degree of carbonization of existing concrete –

Photo 7;

- Establishing the type and technical parameters of existing steel reinforcement by direct scanning – Photos 9 and 10.

All tests are performed in accordance of actual national BG and EN standards.



Photo 1 Pool general view



Photo 2 Pool general view from above



Photo 3 Crack width measuring



Photo 4 Crack width measuring



Photo 5 Core cutting



Photo 6 Bottom slab core №3 with length 25 cm (lower steel reinforcement Ø8 cm, located at 17 cm from the upper edge of the bottom, only)



Photo 7 Zero concrete carbonation established by colorization method



Photo 8 Concrete compressive test



Photo 9 Direct scanning existing steel reinforcement



Photo 10 Direct scanning existing steel reinforcement - visualization

The most of obtained objective results from the implementation of the planned specialized measures within the framework of the constructive inspection for the condition of the bearing steel-

reinforced concrete construction of the facility can be summarized as follows:

- The experimentally determined compressive strength class of the executed concrete for the walls and bottom slab is C30/37, exceeding the design one (C12/15);
- It was found zero carbonization in the cross section, which means that the steel reinforcement is reliably protected against corrosion;
- The design details for the implementation of the bottom slab are not performed correctly, both in terms of design thickness and in terms of the method of reinforcement - the waterproofing of the “lower edge” elevation provided in the project is missing, design thickness of 20 cm has not been observed (there are thicknesses between 7 and 27 cm), only the lower steel reinforcement of Ø8 in 20 cm is made, instead of the designed double one of Ø12 in 15 cm;
- The design details for the construction of the walls of the pool have not been fulfilled, too - Instead of two rows steel reinforcement with Ø12 in every 15 cm, two rows Ø8 in every 20 cm are made, the project lacks a connection detail (with watertightness provided) between the individual stage of the walls casting.

Summarizing all mention above, these are the main reasons for the defects and damages found during the operation of the facility.

2.2. Technical solution for repairing

Taking into account all structural and technological consideration, plus the results and conclusions from the structural investigation performed, innovative technical solution for repairing works is proposed - Fig. 1 and 2:

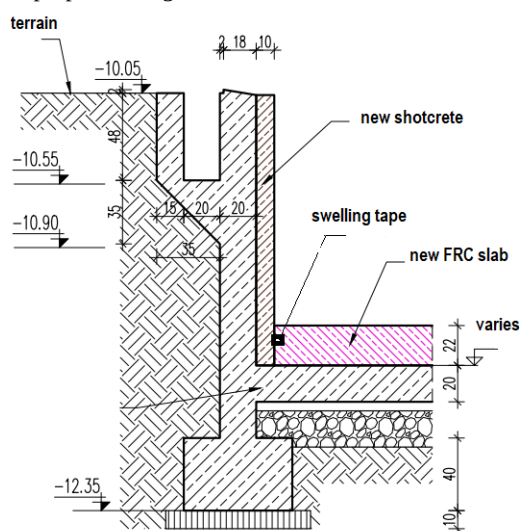


Fig. 1 Principal cross-section

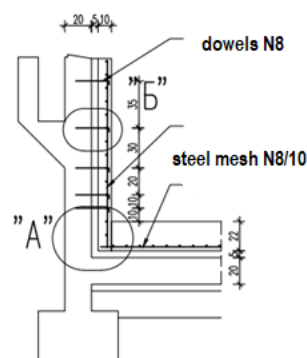


Fig. 2 Cross-section steel-reinforcement

- **NEW WALLS** - thickness 10 cm, reinforced with N8/10 mesh made of B500 steel (doweled in the existing walls), executed by on the existing walls without removing the existing finish. One-stage execution without any joints.

Concrete requirements: High-tech fine-grained ($D_{\max}$ 8 mm) fiber-reinforced waterproof sprayed concrete with compressive strength class C35/45, micro-polypropylene fiber-branched 12/18 mm (dosage rate 1,00 kg/m³), 4G-internal crystallization chemical admixture KRYSTALINE Add1 (dosage rate 1,0 kg/m³), shrinkage compensating admixture KEPTONITE (dosage rate 15,00 kg/m³), high-range water reducing agent, with additionally resistance to aggressive environmental factors XC3, XF3, XD2 and consistency class S2 with water-cement ratio below 0,45.

- **NEW BOTTOM SLAB** - thickness 22 cm, reinforced with N8/10 lower mesh made of B500 steel, executed on the existing bottom slab without removing the existing finish. One-stage execution by power floating machines without any joints.

Concrete requirements: High-tech ordinary-grained ($D_{\max}$ 22,4 mm) fiber-reinforced waterproof pumpable concrete with compressive strength class C35/45, micro-polypropylene fiber-branched 12/18 mm (dosage rate 1,00 kg/m³), steel fibres HE 0,75x35 mm (dosage rate 25,00 kg/m³), 4G-internal crystallization chemical admixture KRYSTALINE Add1 (dosage rate 1,0 kg/m³), shrinkage compensating admixture KEPTONITE (dosage rate 15,00 kg/m³), high-range water reducing agent, additionally with resistance to aggressive environmental factors XC3, XF3, XD2 and consistency class S3 with water-cement ratio below 0,45.

The main principle of the proposed technical solution is the requirement that the repair work on the walls and bottom slab to be carried out in one technological cycle (stage), without any joints. In this way the best adhesion connection between the walls and the bottom is achieved and the watertightness of the facility is ensured. In such a direction is the need to install in detail and water-swallowable tape in the contact zone between the bottom and the bottom. The security of the proposed jointless solution is based on the specific action of the included special chemical admixtures [2,3] and the method of hybrid reinforcement - a combination of conventional steel reinforcement and disperse reinforcement, including different types of fibers.

2.3. Execution of the solution

All designed structural repairing works are executed in one-stage in the of February, 2022. Fresh concrete is produced in the new equipped respective batching plant ECOMIX in accordance of specially prepared concrete mix design.



Photo 11 ECOMIX concrete batching plant



Photo 12 Walls and bottom slab steel mesh fixing

The concrete casting sequences fully complied to the planned one – at first all walls shotcreting works are finished and after them the bottom slab casting was started.

Shotcreting is performed by using 2 specialized machines and compressors, working in parallel - Photos 11-14. After that bottom slab concreting was started by using additional stationary concrete pump. The finishing works were based on special power floating machines.



Photo 13 Concrete pumps used



Photo 14 Piping for concrete horizontal transport



Photo 15 Walls shotcreting



Photo 16 Walls shotcreting



Photo 17 Bottom slab concrete casting



Photo 18 View of finished concrete works

Approximately 250 m³ innovative sprayed and conventional concrete were casted, as the entire structural repairing works are completed and finished in range of 18 hours. After respective concrete curing measures additional polymer-finishing works will be in progress. Dead line of all repairing works is the end of April, 2022.

3. Artificial lake

In pursuance of the investment program of the SOFIA CITY MUNICIPALITY, in the period 2019-2021 a complete renovation of "West Park", the second largest park in Sofia, was in progress, including emblematic for the city parts of it - the artificial lake and rock garden.

We proposed an innovative technical solution for the execution of concrete works on walls and bottom slab by using high-tech hybrid fiber-reinforced sprayed concrete according to a specially developed recipe of a multifunctional capillary crystallization system for permanent autogenous waterproofing of concrete, based on the use of a deep crystallizing chemical additive KRYSTALINE Add 1 (dosage rate 1,0 kg/m³ concrete) - Fig. 3.

One stage of concrete slab and walls spraying in participation of KRYSTALINE Add 1 and special admixture KEPTONITE (dosage rate 15,00 kg/m³) for full range shrinkage controlling, leads to form completely joint-free water-tight structural system. This innovation makes it possible to eliminate the need for all additional waterproofing works.

The implementation was carried out in the autumn of 2020 by TORCREET EXPERT Ltd. in a continuous production process for 20 hours with parallel use 3 teams with three sets of mechanization - modern shotcrete machines and technological kits to them, pipelines and spray nozzles.

After two weeks of curing the sprayed concrete, in accordance with the developed architectural and landscape project, the

installation of the lining of part of the lake walls with natural stone (granite), laid and adhered to the executed sprayed concrete using high quality polymer-modified silicate binder material.

After nearly a year of trouble-free operation, the overall implementation of the project creates a unique art vision of the lake, rock garden and the surrounding park area.

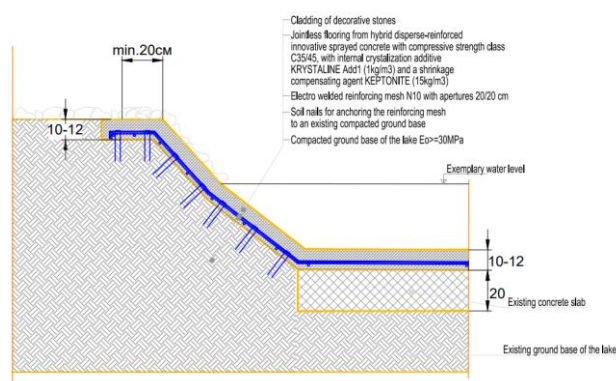


Fig. 3 Cross-section detail

This pilot implementation creates objective preconditions for expanding the range of innovative structural systems, which, in addition to specific structural functions, are also applicable as opportunities for aestheticizing the urban and park environment.



Photo 19 Deployment of two concrete pumps for simultaneous operation



Photo 20 Wall spraying



Photo 21 Wall spraying



Photo 22 Finished area – walls and bottom slab



Photo 23 Final art vision with natural rocks lining



Photo 24 Final art vision with natural rocks lining

4. Conclusions

In summary of the above, it can be argued that the use of high-tech hybrid reinforced sprayed “wet” concrete for the construction and repair of water facilities is an innovative approach with certain advantages. The inclusion in the concrete mix design high-performance special chemical internal-crystallization chemical admixtures improve the watertightness of the cross-section with

additional benefits for self-healing of cracking. Additionally proposed shrinkage compensating admixture allows to design and execute some join-free surface concrete structures (walls and bottom slabs), without organization of different types of joints – daily, cold and saw cut etc.

The proposed and successfully implemented innovative technical solutions for specific water facilities are a good prerequisite for successful expansion of the scope of this approach, which increases the efficiency of the performed repair works and shortens the construction period.

Acknowledgments

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Comparison of different position controllers implemented with a Beckhoff controller and TwinCAT 3 software

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Abstract: Achieving the required dynamics and accuracy of movement of electromechanical linear axes is one of the basic tasks in the field of modern production machines and devices. In addition to a sufficiently powerful electric motor, e.g. electric servomotor, the appropriate controller and control concept also play a key role. As the top performance of the electromechanical axle controller is still a key feature of efficient and quality production, this topic is discussed in this paper.

At the forefront of the paper are the development and implementation of various position controllers developed in the Beckhoff TwinCAT 3 environment. In addition to the classic PID controller already available in the Beckhoff software, a special PID controller has been developed in the Matlab / Simulink environment, as well as a Fuzzy controller and a Feedforward control strategy. For all mentioned types of controllers, the basic characteristics, design approach and parameterization of the controllers are presented. The efficiency of individual position controllers on an industrial-type electromechanical linear axis, driven by an electric servomotor, was tested experimentally and the results are compared.

The efficiency of these closed loop controllers was also tested in terms of robustness and ability to adapt to changes in the control loop, where a different load of moving mass was used as a characteristic change in the control loop.

Keywords: ELECTROMECHANICAL LINEAR AXIS, POSITION CONTROL, BECKHOFF TWINCAT 3, CONTROLLERS

1. Introduction and test device structure

Different approaches and concepts, as well as different hardware and software, are used to control the linear servo axis, which are often used within industrial and other manipulators. In the present case, a powerful Beckhoff industrial controller and the Visual Studio software environment with the TwinCAT 3 software add-on or software extension were used. In the TwinCAT 3 environment, different types of controllers were first designed and then implemented and compared.

The designed system allows to implement different types of controllers suitable for position control. Among them was also self-developed customized PID type controller, which was designed in the MATLAB-Simulink software environment. This was designed and used due to the limited possibilities of using the existing PID controller. Except the classic and customized PID controller, a non-linear controller based on Fuzzy logic was also designed and tested, as well as Feedforward control strategy. All types of controllers were tested, and their effectiveness was compared based on the step response to a constant change of position at a constant load. [1], [2]

For the linear axis control, it was used a servomotor that allows precise control of speed, acceleration, and position. The servomotor is controlled by a closed loop via the position sensor, as shown in principle in Figure 1.

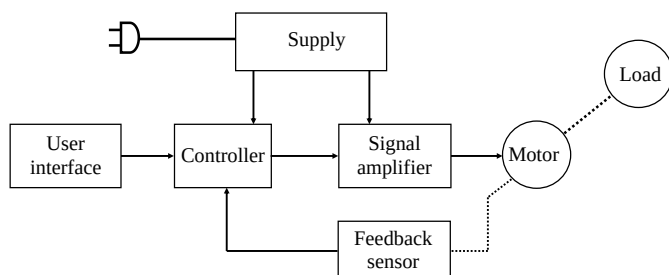


Fig. 1 Basic structure of the servosystem.

The control system consists of a trajectory generator and a linear axis as a controlled object - Figure 2. From the trajectory generator, the position reference r and the rate of change of the position reference (trajectory tangent) dr are led to the input of the tracking system. The controlled system is implemented according to the cascade principle. Speed and current loops are already available and set inside the Beckhoff controller.

The considered system for practical testing of different types of controllers consists of electrical, mechanical, constructional and control elements. The Festo linear axis of the FESTO-DGE-25-500-

ZR-LV-RV-KF type converts the rotational movement of the servomotor into a linear displacement by means of a toothed belt and is designed for medium loads. The Beckhoff servomotor type AM8113-0F20-0000, which has an integrated 18-bit absolute incremental encoder, is used as a linear axis drive. The linear axis is connected to the servomotor motor via a toothed belt, which allows us to move the trolley with the load quickly and dynamically.

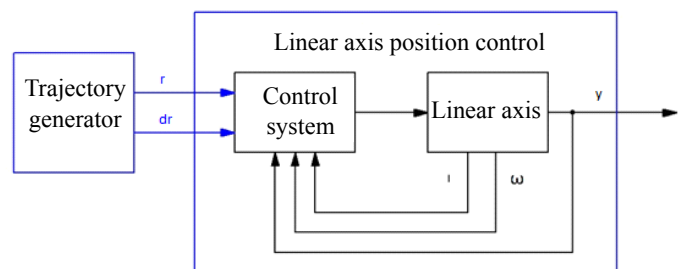


Fig. 2 Block diagram of the considered system.

Up to 5 kg of weights can be attached for variable weight regulator testing purposes. Shock absorbers are installed at the end positions of the linear axis to physically restrict the end position of the trolley. The additionally installed pneumatic cylinder supplied with a pressure of 2 bar and actuated via a controller, represents an additional switching load to generate additional movement disturbance.

The entire linear axis, together with the supporting frame, is mounted on a table under which the controller and power supply and the corresponding electronics are installed. The actual appearance of the entire system is shown in Figure 3.

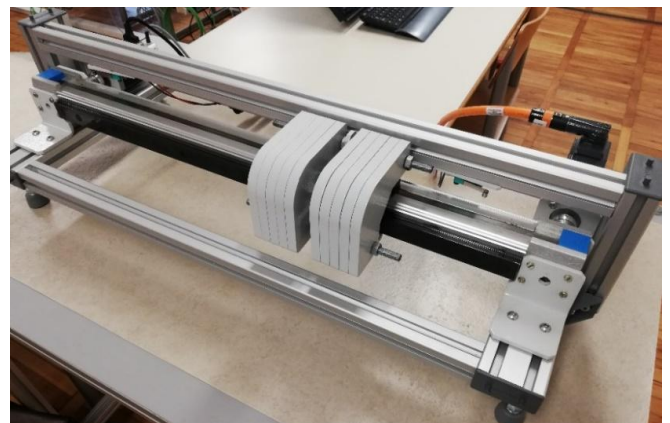


Fig. 3 The actual appearance of the test facility.

2. User interface – graphical form

To create a more complex and sophisticated user interface, the user interface between the user and the TwinCAT 3 software environment (HMI) was created in Visual Studio C# Windows Forms Application, which is designed to build graphical applications. As shown in Figure 4, the user interface allows us to select different types of controllers: P, PI, PD and PID as well as the Fuzzy controllers and customized controller type. It also allows setting all the necessary parameters of different types of controllers as well as control devices and selecting/entering a new setting value for the system. After enabling the motion, the response can be monitored and recorded on the right side of the screen by using *Scope* function that was implemented in the WinForms application.

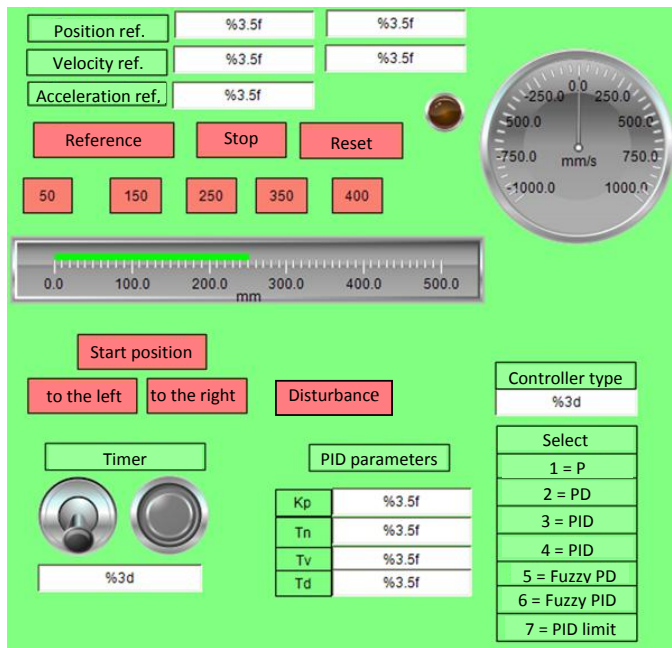


Fig. 4 Graphical form of the user interface developed in Visual Studio C# as Windows Forms Application.

The graphical form of the interface is divided into individual sections. The first part is intended to specify the parameters required for system operation. It consists of the desired position, the desired speed (maximum speed) and the desired acceleration (maximum acceleration). The desired values of each quantity are entered in the corresponding empty boxes marked with %, where the actual values are shown next to them.

To make it easier to test individual controllers, hotkeys have been added, as each time entering a value for the desired position is a time-consuming system bottleneck. Clicking on an individual hotkey triggers the transcript of the selected value to the desired position and moves the linear axis to the desired value. Speed keys are defined according to the distance of the linear axis; values 50, 150, 250, 350 and 400 mm (see Figure 4).

Since the main purpose is to test and compare different types of controllers, the possibility of quick selection of the type of controller is added. In this way, when changing the type of controller, it is not necessary to interfere with the program code and reload it on the control unit. For the selected controller, it is only necessary to enter the controller number, which is listed in the table below the controller selection. For optimal setting of the response on the controller, the possibility of changing individual parameters for the selected controller is added (on the left side of the controller selection table).

In case the system loses power, it also loses information about the location of the axis - so the "Start position" button was added, which moved the linear axis to the limit switch and set the starting position to "0". With the buttons "to the left" or "to the right", the linear axis moves in the selected direction, at a certain speed,

regardless of the setting of other parameters. The "Disturbance" button is used to trigger the disturbance function – triggering the pneumatic additional load (if necessary – disturbance response).

In addition to the mentioned parameters, a timer is also available. With the timer we were able to set the time of movement of the linear axis in the desired direction.

The graphical interface also displays values for the current speed and current axis position in graphical form. The "speed indicator" is used to display the speed (in mm/s), which shows the current speed value with the help of a pointer and a circular scale, and a linear position scale with a green slider (in mm) is used to display the position (Figure 4).

3. Controller design in TwinCAT 3 environment

The system allows closed loop control of either the servomotor or the stepper motor (optional) using different control concepts. In our case, the use of a servomotor was at the forefront.

Servomotor control is performed by two control systems. One is implemented by a virtual controller and the other is implemented in the servo motor control module (Beckhoff EL7211). For the control system that is operated by a virtual controller, we can also select the controller type in the *Motion (Axis – Ctrl tab)* and set the control parameters.

The control system in the "EL7211" servomotor control module, which drives and controls the servomotor, is implemented in a cascade procedure. Figure 5 shows the control diagram, which represents the already mentioned cascade control for the control of the AM8113 servomotor (Beckhoff) used. Cascade control in this case consists of three controllers. These are the position controller, the speed controller, and the current controller.

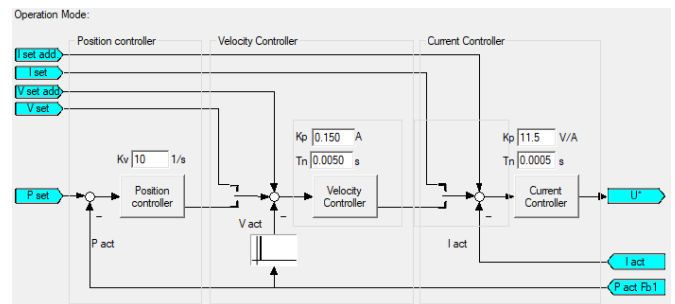


Fig. 5 TwinCAT 3 cascade closed-loop controller for servomotor.

Complex system control often cannot be achieved with a single feedback loop. The reason for this is that complex systems are managed based on only one information about the system and that is its output size. The controller reacts to changes that occur within the system only when their effect is expressed on the output of the output quantity. This usually results in a slow response to the control error. Therefore, cascade control is often used in automation, where it is necessary to have fast and exact response of the system. [3]

In the considered case, the cascade control system consists of two control loops, with an inner and an outer loop, with the outer loop being the superior or main loop. In such a cascade structure, the main controller does not act directly on the actuator but forms a reference value for the internal loop, slave controller. The effect of a fault in the auxiliary control loop is practically compensated in this loop. The output of one controller changes the set-point of the auxiliary controller. Each controller has its own variable that is measured in the process.

Cascade control is only effective when the dynamics of the internal control loop is much faster compared to the dynamics of the external loop; for example three times faster. If the inner loop is not much faster than the outer one, there is a great chance of interaction between the two loops that can cause instability [3].

3.1 Matlab/Simulink PID controller

In the scope of this research a Matlab/Simulink PID controller was developed to confirm the adequacy of importing and using Matlab/Simulink controllers on Beckhoff soft PLCs, which will further allow us to design and implement other types of controllers, such as nonlinear closed loop controllers. The Matlab/Simulink software environment enables us to generate program code for the TwinCAT 3 software environment, in which we design the system control program. Thus, we can directly convert the designed controller model into the TwinCAT 3 program code. Thus, at first step, we have only implemented the PID controller in the Matlab/Simulink software environment and compared the response of the implemented controller with the response of the TwinCAT 3 NC Axis system controller.

The implemented PID controller was designed in the Matlab/Simulink software environment with sampling time of 1 ms, as the execution on the controller is discrete and not continuous. The sampling time had to be the same as set in the TwinCAT 3 software environment project.

The transfer function of the PID controller is already available on the Beckhoff website - Equation 1 [4]. The equation had to be converted from the continuous form to the discrete form shown by Equation 2.

$$[G_{PID}(S) = K_p * (1 + \frac{1}{T_n * S} + \frac{T_v * S}{1 + T_d * S})] \quad (1)$$

$$G_{PID}(Z) = K_p * (1 + \frac{1}{T_n} * T_s * \frac{1}{z-1} + \frac{T_v * \frac{1}{T_d}}{1 + \frac{1}{T_d} * T_s * \frac{1}{z-1}}) \quad (2)$$

The transfer function is built from individual blocks, which need to be named and connected into a whole - Figure 6.

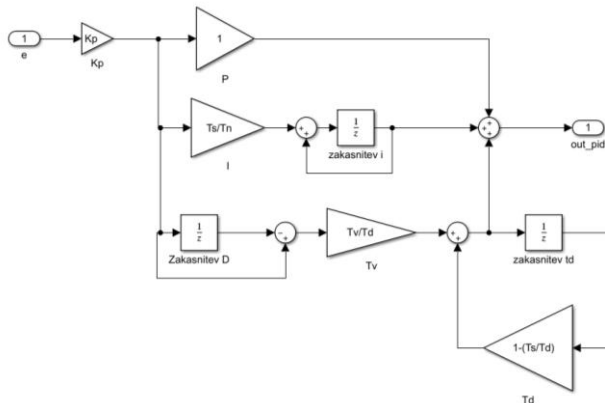


Fig. 6 PID controller developed in Matlab/Simulink.

The created diagram in Matlab/Simulink is then used to create Subsystem and prepare it to generate code suitable for import into TwinCAT 3 software environment. The generated code is then imported into the TwinCAT 3 program as POU using the import function (PLCopenXML format). This generates a program block including the created controller with corresponding input and output variables.

3.2 Fuzzy PID controller

The Fuzzy PID controller was also designed using the MATLAB-Simulink software environment. The process of designing a Fuzzy PID controller is basically the same as the described process of designing a classic PID controller, so only key differences will be mentioned.

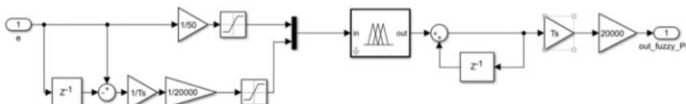


Fig. 7 Fuzzy PID controller.

The differences are in the scheme, the equation which is used to make the controller and the subsystem block. For the Fuzzy PID controller, the transfer function shown in Figure 7 was created using blocks.

3.3 Feedforward controller

In principle, we use the Feedforward control system to perform fast movements that do not have enough time to obtain feedback or if we want to speed up the operation of the system. The response is thus faster than the time required to receive, process, and control the signal. With such control, the disturbance is detected and considered before it affects the system. Figure 8 shows, for comparison, a scheme of a system without a controller - open loop (a) and a system with a feedforward controller, which compensates for the influence of disturbance (b) [5].

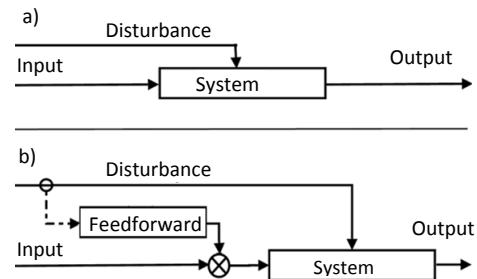


Fig. 8 Non-controlled system (a) and Feedforward system [5]

Since we do not usually know the exact transfer function of the control object, and because the real system is not linear, it makes sense to use a combined system with a feedback loop of the controller. The block diagram of the combined system is shown in Figure 9.

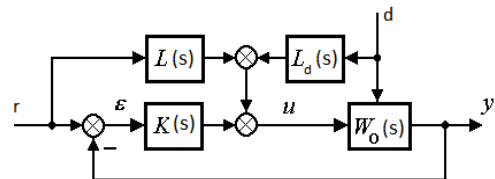


Fig. 9 Structure of combined system [5].

The block diagram of the combined control system in the variant with PID controller is shown in Figure 10 and in the variant with Fuzzy controller in Figure 11.

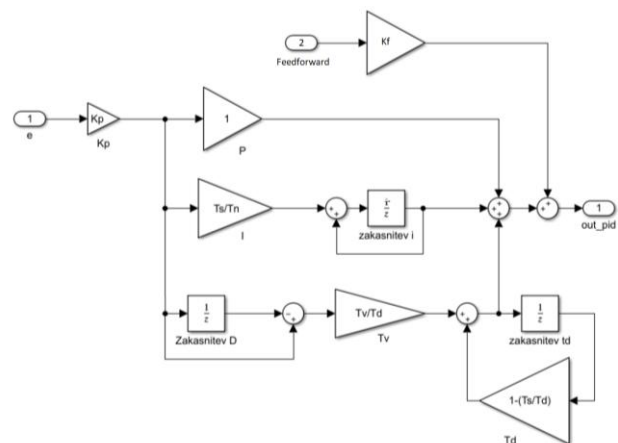


Fig. 10 Block diagram of Feedforward with PID controller.

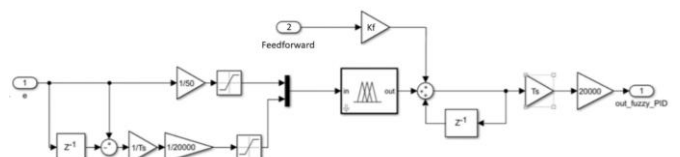


Fig. 11 Block diagram of Feedforward with Fuzzy controller.

4. Results and comparison

The aim of the research was not only to control the linear axis using Matlab/Simulink designed and implemented PID closed loop position controller, but also to evaluate its proper operation and response, which was achieved by comparing the responses of the TwinCAT 3 PID controller and other controller types. In this way, we were able to verify that the axis control system and the closed loop controller were properly designed and implemented. In case we have implemented everything correctly, the behavior of both systems should be the same. Figures 12 to 15 show the responses of the system using presented controller types for the case of minimal load (0,5 kg). The green line represents the set-point change, while the orange line shows the generated position trajectory representing the set-point value and the red shows the actual axis position when moving relative to the generated trajectory. The figures clearly show that the responses different position controller is more or less identical.

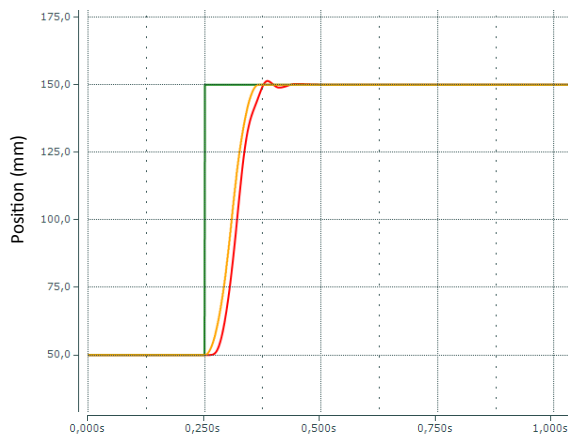


Fig. 12 Step response - PID controller optimized by Ziegler-Nichols method.

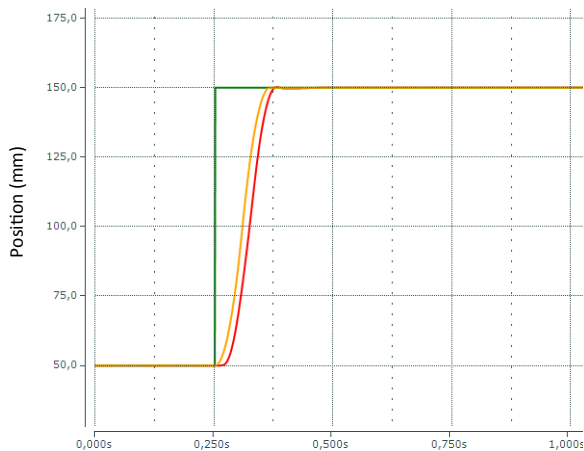


Fig. 13 Step response - Fuzzy controller

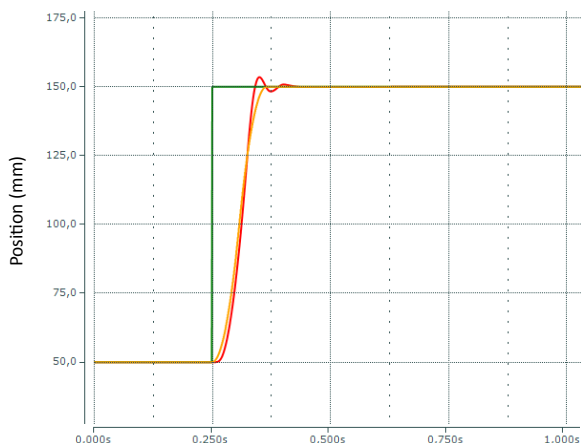


Fig. 14 Step response - Feedforward and PID controller.

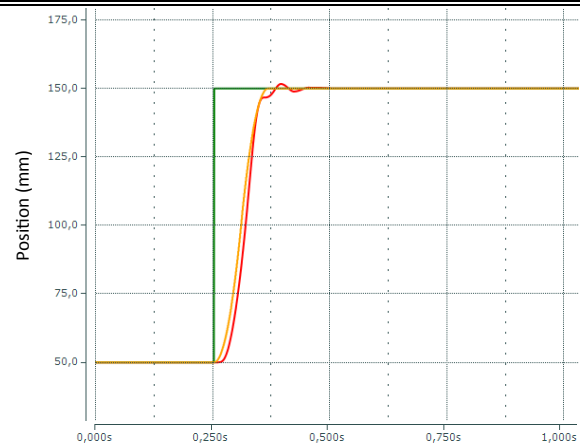


Fig. 15 Step response - Feedforward and Fuzzy controller.

5. Conclusion

The main goal of the research was to build a linear feed system consisting of an industrial type of servomotor to test the design and implementation of different types of controllers suitable for use in the Beckhoff TwinCAT 3 system. On this purpose the TwinCAT 3 PLC program and corresponding user interface for controlling the system was developed in Visual Studio C# WinForms application. This enabled the implementation and testing of various types of position controllers. In addition to research related to different types of controllers, the system allows research into the dynamic behavior of the system in the case of a step input change of position, the dynamic behavior in the case of a disturbance e.g. when changing the load as well as the combined step-disturbance behavior, all for different loads.

The design and implementation of PID position controller from Matlab/Simulink software environment into TwinCAT 3 system allows us to use more advanced, more complex, more responsive, and faster controllers - from the classic PID type, nonlinear Fuzzy controller, and Feedforward control strategy. We can compare different controllers for each system, so we can choose the most optimal controller for application needs. By adding even more different controllers, we gain the ability to test and compare new high-end controller concepts and are no longer limited to TwinCAT 3 controller types.

By confirming the results - approximately the same dynamic responses of different types of regulators, the adequacy of the process of development and implementation of closed loop controllers from the Matlab / Simulink environment is confirmed.

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Application of submodeling in strength analysis of horizontal tank for storage of petroleum products

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Abstract: This paper shows the approach of submodeling in finite element analysis in process of designing the horizontal tank for storing petroleum products. Those kinds of tanks are made at exact standards or slightly altered by customers' demands. Before the numerical analysis of the tank, the tank standards are described as well as numerical analysis. In the paper, the methods which will be used in obtaining solutions by finite element method were described. 3D finite elements have been used for numerical analysis. After getting the results of full tank model meshed with 3D tetrahedral final elements, the technique of submodeling has been used to achieve more accurate results in critical locations of the tank. In the final aspect, result analysis was conducted, where the results were confirmed so that the tank complies with the standard and meets all the criteria given to the designer.

Keywords: FINITE ELEMENT METHOD, SUBMODELING, HORIZONTAL FUEL TANK, LIFTING LUG

1. Introduction

Fuel tanks are used for the storage of various types of liquid fuels, fuel oils and similar liquids with a maximum density of up to 1,9 kg/l, which assigns fuel tanks to Class A according to the relevant standard which is used in this analysis EN 12285-1:2018. [1]. They are manufactured as single-wall and double-wall tanks. Single-wall tanks are used when the tank is located in a location that protects the environment from possible fuel leaks. With double-wall tanks, there are no restrictions on the location of the tanks. Double-walled tanks allow continuous leakage control (negative or positive pressure) and provide long-term safety in use [2].

Fuel tanks are considered pressure vessels subjected to tensile forces within the walls of the container. The normal stress in the walls of the container is proportional to the pressure and radius of the vessel and inversely proportional to the thickness of the walls. [3]. Pressure vessels and tanks are different in both design and construction: tanks, unlike pressure vessels, are limited to atmospheric pressure; and pressure vessels often have internal pressure while most tanks do not have that [4].

It is imperative for an engineer to design and analyze the pressure vessel that will provide safety, durability and serviceability to the end user. Accomplishing this task will require a very good knowledge of design parameters, the most important being, geometry of pressure vessel that must be analyzed to comply design standards [5]. For this reason, many studies have been carried out to explain the design and finite element analysis of horizontal tanks on saddle supports [6-9].

The standards also include lifting lugs for transporting and lifting tanks. Each tank must be equipped with lugs for lifting the tank. The number of these lifting lugs shall be at least one for a tank up to 20 m³ and not less than two above 20 m³. They shall be placed so that the tank can be lifted in a horizontal position. The lugs welded to the tank shall be of such size and number that the empty tank can be lifted. The minimum diameter of the hole on the tank lifting lug must be 60 mm [1].

This paper presents the results of the numerical analysis of the strength of the horizontal tank used for storage of petroleum products. The ANSYS 18.0 [10] software package was used to obtain the results of the stresses and strain in the tank. Before using the ANSYS software package, it was necessary to create a 3D model of the tank to be used in the software. The tank 3D model was created in SOLIDWORKS 2021 [11].

2. Problem description

This paper aims to verify the structure of the horizontal tank for storing oil derivatives and determine whether design changes are needed. The verification will be performed by determining the equivalent von Mises stresses and the maximum total displacement of the fuel tank. The results are acquired by comparing the stresses obtained by FEM analysis from global model and for each submodel.

Fuel tanks are normally mounted on two stands. The stand can be welded to the tank or can be movable in relation to the tank. The baseplate has holes for fixing the plinth to the base plate and the ribs have holes for the floor connection. The plinths are primed and given a final coat of paint, i.e. bitumen board or Recitol if the plinth is used for the installation of tanks in the excavation pit [12]. An overview of the tank model developed in the SOLIDWORKS 2021 software can be found in Figure 1.

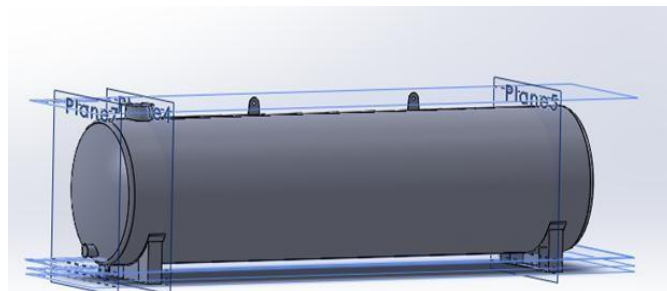


Fig. 1 3D model of horizontal tank for storage of petroleum products

The tank is used for the storage of petroleum products (liquid fuels up to 1,1 kg/l) with wall thickness of 7 mm and is supported by two saddles, which are also made according to the standards for the tank manufacturing. Investigated tank is manufactured according to standard mentioned earlier in the paper. Its dimensions and other data can be seen in Figure 2. As this is a 50 m³ tank, a lot of computational power is needed to create a high-quality mesh for the meshing of a geometric model from appropriately selected finite elements.

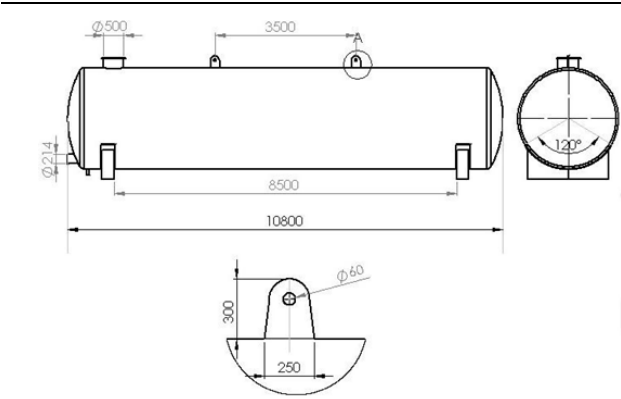


Fig. 2 Dimensions of the 50 m³ horizontal tank

3. Finite element analysis of the global model

In order to obtain the required results, material properties of steel S235JR are assigned to the model. The Young's modulus of elasticity $E = 210$ GPa, yield strength $R_{p0.2} = 235$ MPa and the value of Poisson's ratio $\nu = 0,3$ [13, 14].

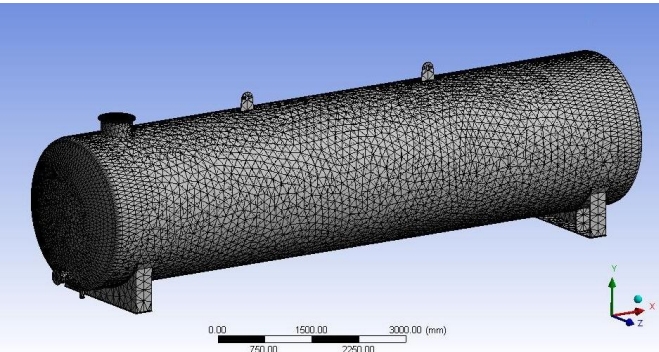


Fig. 3 Display of a 3D finite elements mesh

Global model with a coarse mesh is made with tetrahedral finite element mesh size of 100 mm and boundary conditions are applied (Figure 3 and Figure 4). Total number of finite elements in global model is 54271 with 106702 nodes. As a boundary condition, fixed support is used as well as displacement support with restrained y-direction and a test pressure of 0,2 MPa is set.

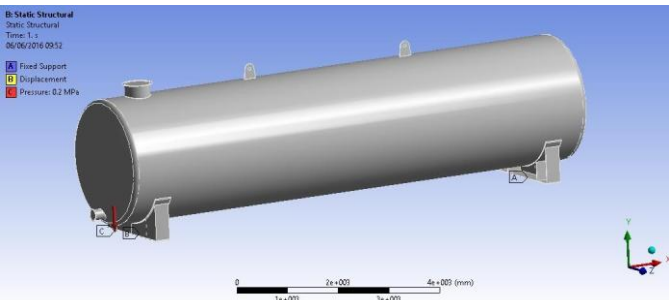


Fig. 4 Boundary conditions of the 3D model

The representation of the equivalent von Mises stresses in the 3D model is shown in Figure 5. With the 3D model, the highest stresses are at the junction between the cylindrical and the bottom part of the tank. The magnitude of the maximum equivalent stresses is 191,76 MPa.

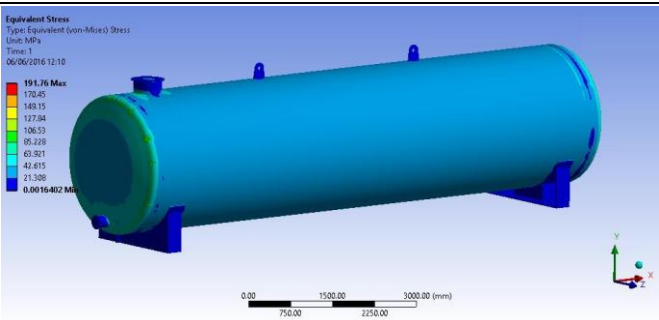


Fig. 5 Distribution of the equivalent von Mises stress

It can be seen that for largest part of the tank, the stress intensity does not exceed 50 MPa. The distribution of the total displacements can be seen in Figure 6. The top opening is analyzed in more detail as submodel in order to obtain more precise stress distribution. The displacements in the largest part of the tank are very small and the maximum displacement is 2,2057 mm at the opening of the tank.

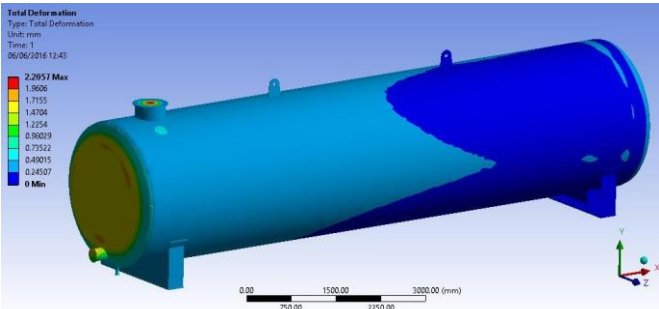


Fig. 6 Global model distribution of the displacement

4. Finite element analysis of submodels

All material and test pressure data given previously were used to obtain results for the tank opening submodel. Displacement results obtained from the global model with coarse finite element mesh are imported into the submodel of the opening, and mesh refinement of submodel is done to obtain more accurate results.

The finite element mesh convergence of the 3D submodel is performed to determine adequate mesh size. Table 1 shows the data of the number of elements, nodes and equivalent von Mises stress in the submodel of the top opening.

Table 1 Number of elements, nodes and equivalent von Mises stress in the top opening submodel

Element size, mm	25	15	13	11
Submodel node numbers	51912	127338	129423	177553
Submodel element numbers	25780	64423	65320	89918
Maximum equivalent von Mises stress, MPa	194,34	184,74	183,17	185,31

The convergence of the von Mises stress solutions is shown in Diagram 1. It can be seen that the deviations are within 5% between the 15, 13 and the 11 mm finite elements, which means that the finite element mesh size of 11 mm is sufficient enough for acquiring accurate results.

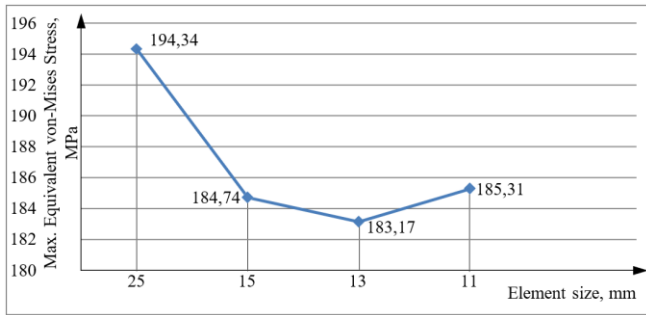
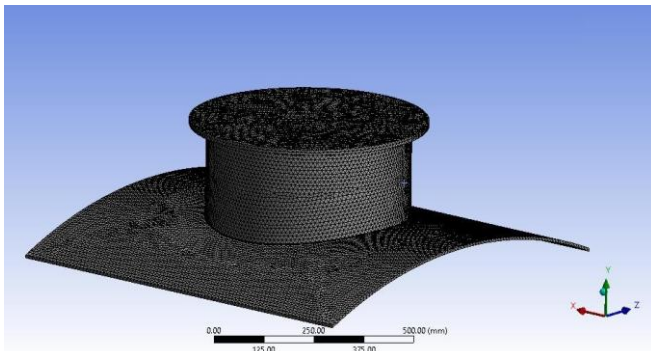
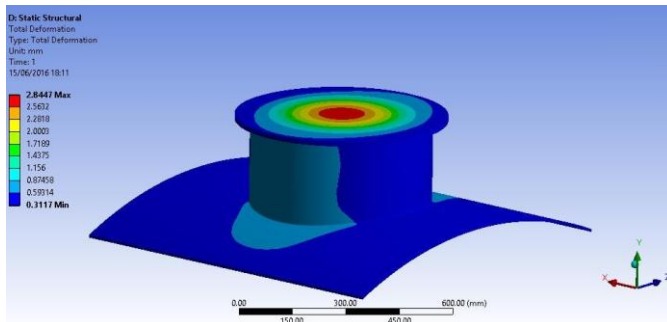
Diagram 1 The convergence of the von Mises stress solutions


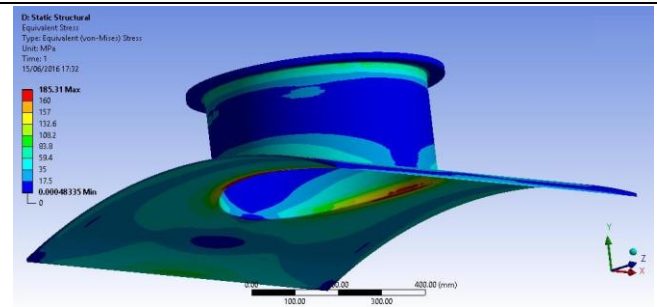
Figure 7 shows a finite element submodel obtained using 11 mm 3D finite elements thus the mesh consists of 177553 nodes and 89912 elements. The mesh in the submodel is significantly denser, showing more accurate results around the tank opening. The submodel of the top opening was created due to the increased displacement and stresses around this area of the tank.


Fig. 7 Submodel with fine mesh of the top opening

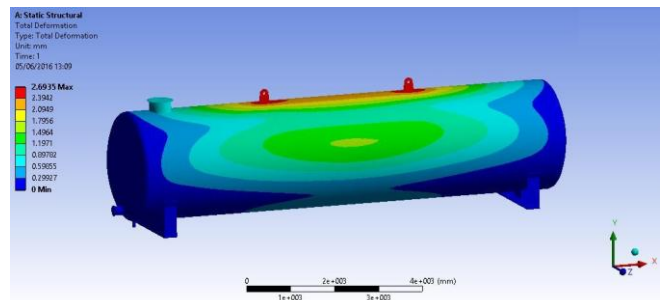
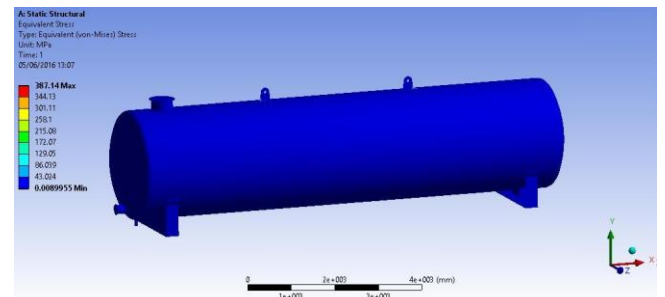
An overview of the total displacements at the tank opening can be seen in Figure 8. The maximum displacement of 2,8447 mm has appeared in the area of the top of the opening.


Fig. 8 Distribution of the displacement of top opening submodel

An overview of the equivalent stresses in the top opening model can be seen in Figure 9. The submodel of the top opening shows increased stresses. By increasing the number of elements in the area of the tank opening, the stresses are approaching more accurate values. The largest stresses occur in the inner part where the top opening and the cylindrical part of the tank connect. These stresses do not affect the safety of the structure and they occur at the edge between the cylindrical part of the tank and the tank opening with maximum value of 185,31 MPa.


Fig. 9 Distribution of the equivalent von Mises stress of top opening submodel

For the calculation of the submodel for lifting the tank as well as for the submodel for opening the tank, it is necessary to use the results of displacement of the global 3D tank model. As a boundary condition for lifting lug submodel, a calculated force of 28318,23 N needed for lifting horizontal tank is applied. Figure 10 shows the distribution of the displacement of the entire model when lifting the tank, and Figure 11 shows the distribution of the equivalent stress according to von Mises. The lifting lug submodel is made in order to get more accurate displacement and stress distribution. During the lifting of the horizontal tank, maximum displacement is 2,6935 mm on the lifting lug.


Fig. 10 Distribution of the displacement of global model during lifting of horizontal tank

Fig. 11 Distribution of the equivalent von Mises stress of global model during lifting of horizontal tank

A detail of the equivalent von Mises stress distribution around the lifting lug is shown in Figure 12. The maximum stress according to von Mises is 387,14 MPa.

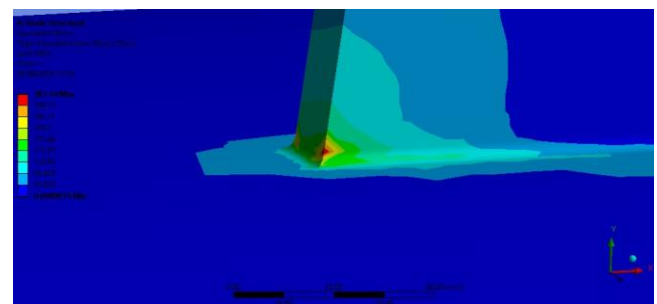

Fig. 12 Distribution of the equivalent von Mises stress of lifting lug submodel

Figure 13 shows a mesh of a lifting lug submodel consisting of 696362 nodes and 423237 finite elements.

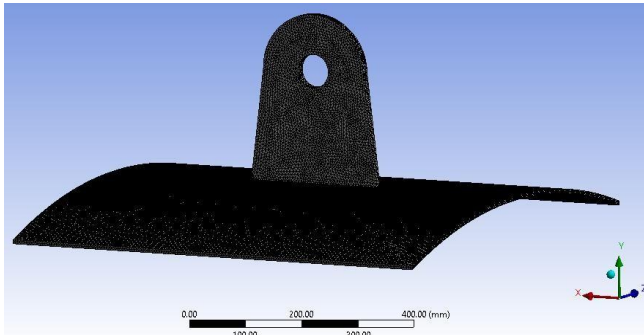


Fig. 13 Finite element mesh of lifting lug submodel

After meshing, lifting force was applied as a boundary condition in the tank lifting lug submodel. An overview of the total displacement distribution of the tank lifting lug submodel is shown on Figure 14. The maximum total displacement is 2,9195 mm. The equivalent von Mises stresses in the lug model are presented in Figure 15.

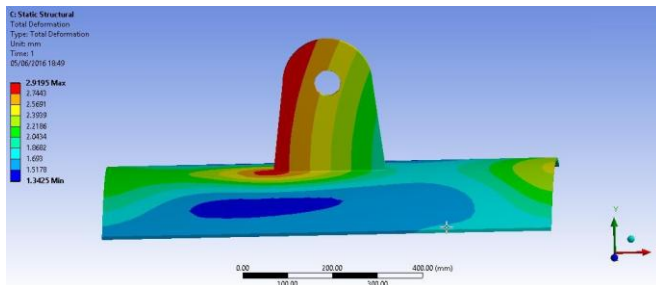


Fig. 14 Distribution of the displacement of lifting lug submodel

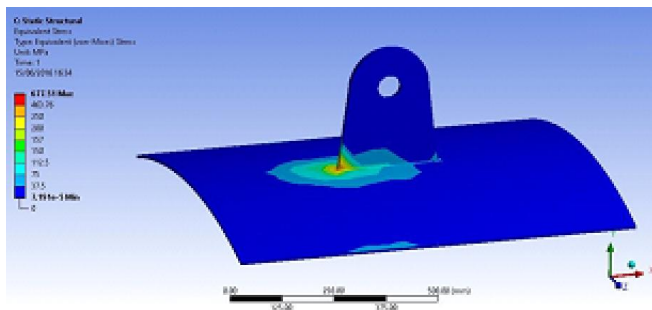


Fig. 15 Distribution of the equivalent von Mises stress of lifting lug submodel

Figures 14 and 15 show a high stress of 677,51 MPa at the joint between the tank and the lifting lug in the area where the lifting lug is not fully welded, due to stress concentration caused by geometry. Significant displacements are not visible in this part. The maximum total displacement is at the very top of the lifting lug and along the edge of the lug. The displacement for this part is 2,9195 mm.

4. Conclusions

Tanks for the storage of petroleum products, like all other tanks, whether pressurized or not, are manufactured according to precisely defined standards. The standards determine everything about the tank, from the materials, dimensions, welds, wall thickness, tank supports, etc. Once the tank volume has been determined and selected, it is necessary to follow the procedure specified by the standards to manufacture the tank. The standard used in this paper is EN 12285-1:2018. Since only some dimensions are defined in the standard, all dimensions must be harmonized to obtain a tank with the desired volume.

In this paper, the CAD / FEM has contributed a lot to confirm the required stresses and strains of the tank. In the paper, the tank is tested as specified in the standard. The test is carried out at a precisely specified pressure, which depends on the application of the tank. To achieve greater accuracy of the results, it is necessary to make the mesh as dense as possible at the location of the stress concentration. Increasing the number of elements and nodes would give more accurate results. Since the design is large and lacks computational power, it was useful to create submodels to describe the displacements and stresses at the tanks locations that are of interest.

At the very end, it can be stated that the tank fulfils all the conditions set out in the paper. The tank complies with the standard and meets all the criteria given to the designer in the manufacture of such tanks.

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Studing the temperature microclimate in beehives made out of defferent materials

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Abstract: The use of clay as a structural material has been known for centuries. The authors set the task of studying the applicability of clay as a constructive material in the production of beehives. The study aims to make a comparative analysis of temperature conditions in different types and identical in construction beehives by comparing the indicator for ceramic and wooden hives. For the purpose were used three 10-frame hives type "Dadan-Blat" - two ceramic (one made entirely of marl clay, and the other - with increased kaolin content, both ceramic tiles are with high cavity) and one wooden (pine). Measurements of the air temperature and the temperature inside the hives were made for one month. From the obtained results it is established that for the studied beehives, the ceramic hive with high kaolin content has the best thermal insulation properties.

KEYWORDS: CERAMIC BEEHIVE, TEMPERATURE

1. Introduction

The last decade has been marked by numerous alarming facts about the extinction of honey bees, without which life on earth would be unthinkable. The reasons for this scary phenomenon are multi-layered and complex. Evidence shows that certainly there is a reason to believe that the living conditions that bees have inside the hives that they are inhabiting are essential for their well-being. Given the advantages of ceramics as a constructive material, it is assumed that it has a high potential to provide favorable and sustainable living conditions for the bee colonies [1]. One of the key factors of the microclimate in the hive is the temperature. The optimal temperature in the breed is around 35-36°C [2]. Higher temperatures can cause the death of the family. Lower temperatures especially temperatures below 0°C will lead to protective diapause behaviour or will have a lethal effect. The extreme temperatures affect the bee products as well. Overheating causes wax melting and too-quick dehydration of the honey while the low temperatures slow down the dehydration of the nectar which causes problems in the production of the honey.[3] The bees have own regulation mechanisms to maintain the healthy temperature of the hive. Whenever the weather is too hot, they start fanning the hot air out or use evaporative cooling mechanisms. If the temperature gets too low they start generating metabolic heat by contracting their flight muscles[4-6]. Both these mechanisms consume high energy of the bees and increase their need for food.

Therefore, it is extremely important to maintain the optimal temperature in the hive. To achieve a better insulating effect, we produce ceramic plates for beehives with standard dimensions for Dadan-Blatt hive with high cavity. The role of well-formed internal cavities is to reduce the coefficient of thermal conductivity inside the hive and to reduce heat loss from the inside to the outside at lower air temperatures. [5-7]

Aim

The aim of the present work is to study and compare the temperature conditions in uninhabited ceramic hives and in a traditional wooden hive, when placed in natural conditions.

2. Methodology

For the purposes of the study, two Dadan-Blatt ceramic hives were made from two different mixtures. The first mixture is made of marl clay from the deposit of the town of Debelelets. The other mixture is with high content of kaolin. High-hollow slabs were made from the two mixtures, from which the two ceramic beehives were made (Fig. 1 - from marl clay and Fig. 2 - with increased kaolin content). A standard wooden (coniferous wood) 10-frames Dadan-Blat was purchased for the experiment (Fig. 3). The hives were placed in a natural environment - Fig. 4



Fig. 1 - from marl clay and **Fig. 2** - with increased kaolin content



Fig.3 10-frames Dadan-Blat was purchased for the experiment **Fig. 4** The hives were placed in a natural environment.

3. Results and discussion

The field measurement was conducted in natural environment in the Industrial Zone of the town of Debelelets, Veliko Tarnovo region. (Fig. 4) On each of the hives were placed digital thermometers model AURIOL, board IAN: 373028_2104, with sensors for monitoring the temperature in the hive and monitoring the outside temperature. The data is displayed. Technical characteristics of the digital thermometer: Table 1 Technical characteristics of the digital thermometer.

Internal temperature measurement range	from -10 °C to +50°C
Outdoor temperature measurement range	From -50°C to + 70°C
Tolerance	from -50°C to 0°C+/-2°C from 0°C to +30°C+/- 1°C from +30°C to + 70°C+/- 2°C
External sensor	IP44 protection against liquid

The measurement was carried out within the period of one month, from 28.04.2022. to 28.05.2022

For the purposes of the study, temperatures are measured at different parts of the day to determine the temperature differences between the air temperature and the temperature inside the hives. The measurements are grouped and analyzed in three categories, according to the information about the optimal temperature in beekeeping. Accordingly, measurements are conducted in cold conditions (at air temperature around 0°C) are differentiated; optimal temperature (between 5°C and 30°C); and high temperature (air temperature above 30°C). The graphs present the average values for the daily measurements made at 00:00, 10:30 and 14:15, respectively.

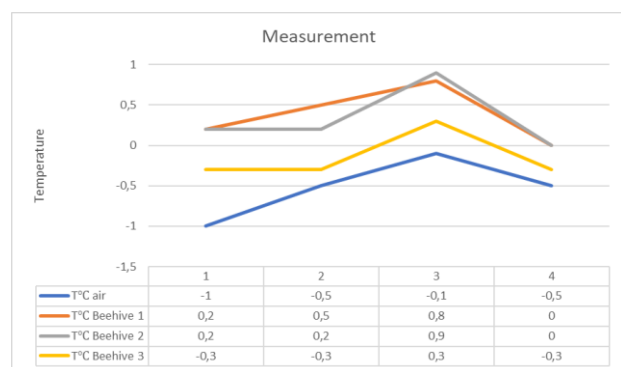


Fig.5 Measurement in cold conditions

When comparing the obtained results, it was found that at low temperatures, in the ceramic hives (hive 1 and hive 2), temperature differences are between 0.8°C and 1°C higher than the outside temperature. In the wooden hive, the temperature is 0.2°C higher than outside.

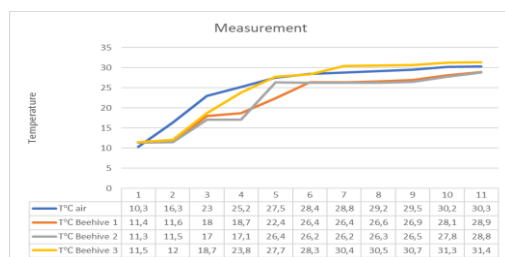


Fig. 6 Measurements during optimal temperature conditions

At optimum temperature, the wooden hive heats up faster than the ceramic ones, as when reaching daily temperatures above 28°C, the difference in temperatures outside and inside the wooden hive is on average 0.2°C, while the difference for ceramic hive 1 is 2.0°C and for ceramic hive 2 is 2.8°C.



Fig. 7. Measurements during heat

During heat, the temperature difference between outside and inside the hive is respectively for Beehive 1 - 2,3°C; for Beehive 2 - 2,6°C; for Beehive 3 - -0,3 °C.

4. Conclusion:

In conclusion, based on the results obtained within the present study, we can say that in cases of sudden temperature changes hive 2 has the highest insulating properties, respectively stable microclimate, followed by hive 1 and hive 3. At the next stage, identical measurement and analysis should be performed with inhabited beehives.

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Use of oriented strandboard in construction industry

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Abstract: In recent years, 3D printing has gradually appeared in people's field of vision. The addition of wood in thermoplastics improve their some mechanical properties such as tensile and bending modulus without affecting its biodegradability. The decrease in the cost of filaments may enlarge the utilization of biodegradable filaments after the disposal in near future. Small-scale elements used in furniture production, such as connector fittings or fasteners for shelves, may give functional and structural properties without significant investment. 3D-printed connections are suitable when the the production complex shaped connectors and quick disassembly are required, to reduce the product's weight and price

KEYWORDS: ORIENTED STRANDBOARD, CONSTRUCTION, WOOD, STRUCTURAL PANEL, ENGINEERED WOOD COMPOSITE

1. Introduction

Oriented strand board (OSB) is produced with the strands in the surface layers aligned in the direction of the long axis of the panel and with the strands in the inner layer either cross-aligned or randomly oriented. Wood strands of about 80-120 mm are cut tangentially from debarked logs which are held longitudinally against rotating knives. After drying, these flakes are generally sprayed with a synthetic resin binder and wax and then bonded under heat and pressure between steel belts. This orientation of strands gives the panel sufficient strength for its structural applications when it is positioned appropriately [1].

OSB is widely used as a structural wood panel for floors (including subfloors and underlays), walls and ceilings. It is used for interior fittings, furniture, shuttering and packaging and also in the manufacture of I-joists, where it forms the web or support between two flanges of solid wood. OSB is being used not only for its structural properties but also for its aesthetic value, with some designers using it as an interior design feature [2]. The oriented strand board (OSB) market size was estimated at over 31 million cubic meters in 2021, and the market is projected to register a CAGR of more than 4% during the forecast period (2022-2027) [3]. Roughly 95% of OSB produced in North America goes to the construction industry. In Europe, about 50% of OSB is consumed for residential buildings [4].

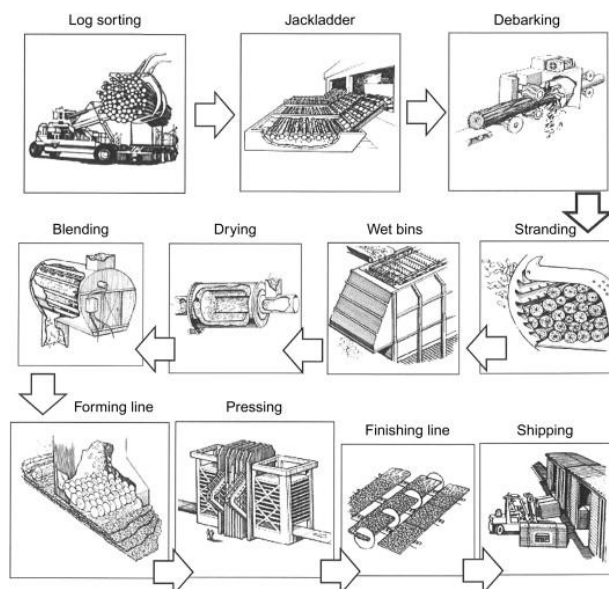


Figure 1. Production line OSB [5].

(OSB) is an alternative to plywood in a variety of structural and non-structural applications.. Advantages of OSB over plywood include no core gaps, uniformity, accurate certification (including the Declaration of Performance and CE marking) and reliable technical information and compared with many plywood sources security in the manufacturer; there is little risk of delamination if used properly [6].

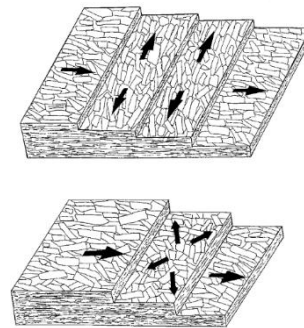


Figure 2. A schematic illustrating strand orientation of a typical OSB.

Four grades of OSB are defined in EN 300 in terms of their mechanical performance and relative resistance to moisture. These are:

OSB/1 – General purpose boards and boards for interior fitments (including furniture) for use in dry conditions.

OSB/2 – Load-bearing boards for use in dry conditions.

OSB/3 – Load-bearing boards for use in humid conditions

OSB/4 – Heavy-duty load-bearing boards for use in humid conditions.

OSB panels may be square edged or tongue-and-grooved to aid in the connection of adjacent panels on site. OSB has particularly good nail-holding properties and can be glued with regular wood adhesives. OSB tongue and groove panels primarily fulfill the load-bearing and reinforcing function during construction.



Figure 3. The or tongue-and-grooved OSB.

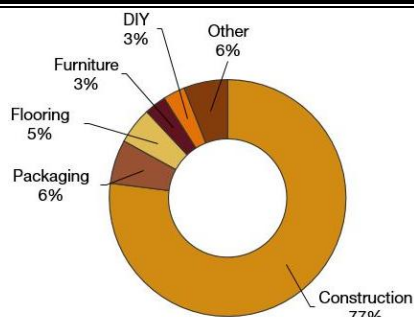


Figure 4. End-use of OSB in 2020 year [8].

Considerations on the use of OSB in construction

Mechanical joints and fixings

Parallel core screws should be used because they have greater holding power than conventional wood screws. A high ratio of overall diameter to core diameter is desirable. Drill pilot holes for all screw fixings. Typically, the holes should be 85 to 90% of the screw core diameter. Fixings into the board face should not be within 8 mm of edges and 25 mm of the corners. Nails and staples can be used for lightly loaded fixings or to hold glued joints while the adhesive sets [1].

Adhesive-bonded joints

A wide variety of jointing methods can be used, provided the following simple guidelines are observed [1]:

- Use sharp cutters to avoid tearing or burnishing the surfaces to be bonded.
- The joint parts should be accurately machined.
- Use a high solids content adhesive with low flowing properties such as polyvinyl acetate or urea formaldehyde.
- Locate mating pieces accurately and hold them under pressure while the adhesive sets.
- The width of grooves machined in OSB should be limited to about one-third of the thickness of the board. The depth of groove is typically about one-half of the board thickness.
- Allow adhesive-bonded joints to condition for several days before sanding and finishing; this avoids the appearance of sunken joints and is essential with high-gloss finishes.
- A tongue and groove joint is very efficient, provided the fit of the joints is not too tight to cause a split along the edge.
- When attaching lippings, the tongue should be machined on the solid wood piece

Finishing

Where smooth surfaces are required pre-sanded panels should be specified.

Like other wood-based panel products, OSB is hygroscopic and its dimensions change in response to a change in humidity. A 1% change in moisture content increases or decreases the length, width and thickness of the different grades of OSB by the amounts set out in the table below [1].

Table 1. Dimensional change of OSB panel depending on the 1% change moisture content [1].

Type of panel	Specification	Dimensional change at 1% change in panel moisture content		
		Length %	Width %	Thickness %
OSB	EN 300, OSB/2	0.03	0.04	0.7
	EN 300, OSB/3	0.02	0.03	0.5
	EN 300, OSB/4	0.02	0.03	0.5

OSB must be conditioned to bring it into equilibrium with its environment before it is fixed. This is usually achieved by loose stacking of the panels in the room where they will be used prior to fixing them. In a building with continuous central heating: 5-7%. In a building with intermittent central heating: 8-10%. In an unheated building: up to 15%. When components are factory produced for installation on site, it is essential that the site conditions are suitable to receive the components with wet trades completed and the building dried out [1].

Table 2. Approximate equilibrium moisture content depend on the relative humidity [1].

Relative humidity at 20°C	Approximate equilibrium moisture content
30%	5%
65%	10%
85%	15%



Figure 5. Flooring application of OSB panel.

All OSB is manufactured to meet the Exposure 1 durability classification, which means panels are appropriate for use where construction delays may occur. Structural 1 panels are for use where shear and cross-panel strength are extra important. For enhanced roof performance, SBA recommends panels with greater span ratings than the minimum required. In fact, by increasing a span rating from 24/16 to 32/16, you can raise the allowable live load of a roof by 75 percent [7].

OSB roof sheathing is characterized by quick and easy installation (Fig. 6). Standard panels are 4' x 8' and come in a variety of thicknesses. Panels must be spaced with a minimum 1/8" gap on all butting edges, and edge clips should be applied when specified. Minimum fastening schedule is 8d nails spaced 6" o.c. at supported edges and 12" o.c. intermediate. Increased panel thicknesses, longer nails, and closer spacing are necessary in high wind areas [7].



Figure 6: Roof application of OSB panel (Fig. 6).

In order to minimize the impact of moisture build-up in attic spaces, it is essential that adequate ventilation be installed with 50 percent of the ventilation at the roof ridge and 50 percent at the soffit area. Building codes specify that the minimum unobstructed vent area equal not less than 1/300 of the total insulated ceiling area. For roof slopes of less than 1 in 6, the free vent area must equal not less than 1/150 of the insulated ceiling area.

SPAN RATINGS (Minimum Panel Width – 24")

Support Spacing	Performance Based OSB Sheathing	
Edges Supported ⁽¹⁾	Span Rating	Common Thicknesses ⁽²⁾
16"	16/0	5/16", 3/8"
	24/0	3/8", 7/16"
24"	24/0	3/8", 7/16"
	24/16	7/16", 15/32", 1/2"
32"	32/16	15/32", 1/2"
	32/20	19/32", 5/8"
40"	40/20	19/32", 5/8"
	40/24	23/32", 3/4"
48"	48/24	23/32", 3/4"
Edges Unsupported		
16"	16/0	5/16", 3/8"
20"	24/0	3/8", 7/16"
24 ⁽³⁾	24/16	7/16", 15/32", 1/2"
32"	40/20	19/32", 5/8"

⁽¹⁾ Tongue-and-groove edges, panel edge clips, lumber blocking or other approved support methods.

⁽²⁾ Panel thicknesses and span ratings apply for pitched or flat roofs; where flat roofs are used as walking decks, the requirements for floors shall apply.

NOTE: OSB sheathing panels are performance rated for, generally, a 30 psf live load (40 psf for 24/16; 35 psf for 48/24). (1 psf = 0.048 kPa)

⁽³⁾ 7/16" (24/16) panels with unsupported edges allowed in some jurisdictions only. Check with local building officials. (1" = 25.4 mm)

Wood frame structures with OSB-sheathed walls perform well against seismic forces or racking shear – much better than concrete or masonry (Fig. 7). Where high winds are of concern, OSB wall sheathing provides peace of mind because of its strength and density. Under all types of exterior cladding, OSB provides extra thermal resistance and acoustic control [8]



Figure 7.

Timber I-joists comprise a timber flange (typically solid timber or LVL – laminated veneer lumber) and a panel product web (usually OSB). Structurally the I-joist works on the principle that the greatest forces in a beam under bending are at the outer faces. Hence, if the stronger tensile and compressive material is positioned at the outside edges, the central zone can be reduced in size as it carries very little of the bending forces. However, the central zone (web) carries the reaction and shear forces [9]. (Fig. 8).



Figure 8.

OSB SIPS (Oriented Strand Board Structural Insulated Panels) are high-performance building systems that consist of an insulating foam core sandwiched between two sheathing layers of oriented strand board. SIPS are an advanced method of construction offering excellent thermal performance, light-weight structural strength and time and cost saving benefits over traditional construction methods. SIPS contribute both insulation value and structural strength to the wall. Walls and ceilings made of SIPS can be constructed quickly by assembling the pre-manufactured panels. SBS Structural Insulated Panels offer extremely high thermal performance, the Polyurethane (PUR) core of rigid insulation and OSB/3 achieves U-Values as low as 0.10 Watts per Meter Squared Kelvin (W/m²K) or better, making significant savings on your annual heating costs [10]. The foam core can be made with expanded polystyrene foam (EPS), extruded polystyrene foam (XPS), polyisocyanurate foam, polyurethane foam, or be composite honeycomb (HSC) (Fig. 9). Vapor barriers are not required in SIP homes, but an interior wall covering must be added [9].

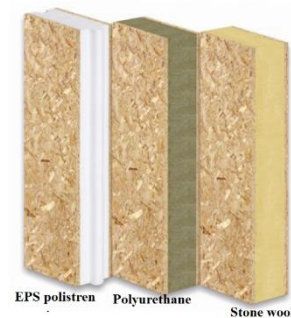


Figure 9. Thermal insulation of OSB panel.

In Canada, OSB panels are manufactured to meet the requirements of the CSA O325 standard. This standard sets performance ratings for specific end uses such as floor, roof and wall sheathing in light-frame wood construction. There are two product standards covering the manufacture of US wood-based panel products:

- US Voluntary Product Standard PS1-19.
- US Product Standard PS2-18.
- APA-trademarked plywood panels are covered by PS 1-19 and PS 2-18.
- APA OSB panels are manufactured to US PS 2-18.

4. Conclusions

OSB is one of the best materials for structural application in the construction industry. Due to its significant advantages. It is cost-effective, practical and much more versatile than plywood. OSB is a dimensionally stable wood-based panel that has the ability to resist delamination and warping. OSB is also used as the web material for some types of prefabricated wood I-joists and the skin material for structural insulated panels

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