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MODERN APPROACHES TO THE FORMATION OF THE CONCEPT OF "MANAGEMENT OF INNOVATIVE ACTIVITY STRATEGY"

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Annotation. The essence of the concept "management of the strategy of innovation activity" is explored. The groups of factors of the external and internal environment that influence the management of the strategy of innovative activity of industrial enterprises are distinguished. The necessity of using methods and tools that will reduce or neutralize the factors of the external and internal environment and increase the effectiveness of the strategy of innovative activity of industrial enterprises is substantiated. The author's definition of the theoretical essence of "management of the strategy of innovation activity" is proposed.

Keywords. Management, strategy, innovation activity, innovation development, process, efficiency, algorithm, stages, factors.

Analysis of recent researches and publications. Domestic and foreign scientists were engaged in the study of issues related to the definition of the theoretical essence, the role of the concept of innovation strategy management in the activity of enterprises, management of the innovation strategy, innovation development management, and innovation activity management, among them: Dudar T.G. [1], Kasyanova L.P. [5], Kozlovsky V.O. [2, 3], Kovtunen K.V. [9], Kolinko N.O. [4], Lebedev I.B. [5], Melnychenko V.V. [1], Novak O.V. [5], Sokolovsky S.A. [7], Stadnyk V.V. [8], Stanislavskiy O.V. [9], Yokhna M.A. [8], Tarasenko V.V. [11], Telenchuk V.S. [10], Shapiro S.B. [11]. Note that for today the essence of the concept of management of the innovation activity strategy is not sufficiently thoroughly investigated, since most researchers carry out an analysis of the concept of management of innovative activity and do not take into account the specifics of this economic category.

Results. The continuous development of a market economy, the emergence of innovative technologies, research and development require industrial enterprises to take timely measures to introduce innovations in order to increase competitive positions, penetrate new markets, gain advantages along with competitors in the production of new types of products or services. Therefore, achievement of the above-mentioned results is possible on the basis of the use of effective strategies of innovation, which are an integral part of the enterprise's activities. The effectiveness of the innovation strategy is achieved on the basis of factors influencing the market environment, that is: at the country level - socio-economic development; the level of taxation of enterprises; optimality of the credit system of commercial banks; the effectiveness of the legislation on the regulation of innovation activity; the level of the investment climate; the experience of world leaders in the development and implementation of innovations; at the enterprise level - coherence of the mechanism of work of the enterprise; level of qualification of the personnel; diversification of production; directions of innovation activity; level of competition; implementation of research and development; assortment of products; the coverage of a particular market segment; the ratio of costs, risks, effects received. In turn, according to the selected group of factors of the external and internal environment, there is a need for the use of methods, means, tools that will reduce or neutralize their effect and increase the effectiveness of the strategy.

Telenchuk V.S. analyzed in detail the features of the management of IA [11], she considered that it covers two areas of operation of the enterprise, namely: investment development, investment capital, resource availability; level of introduction of innovative technologies, production of new products. That is, the author focuses on the feasibility of using innovative technologies, the assessment of environmental factors that will contribute to the development of the enterprise and an incentive for further growth, but left out of attention the strategic aspect, the model of business development.

A similar point of view was observed by Stadnik V.V., Yokhna M.A. [9, p. 74-75], who under the control of the IA considered a complex mechanism aimed at gaining competitive advantage of the enterprise, meeting the demand of consumers, developing a new market of products, subject to the establishment of the process of organization and planning of innovation

The main way that will timely identify the threats of the market environment, develop effective methods of protection, build a clear system of actions for the organization of work and the adoption of sound management decisions, to determine the future options for enterprise activities is to manage the strategy of innovation. Calculated management of the strategy at the enterprise will allow, at the development of new products, to assess the needs of the manufacturer, investors, the domestic and foreign market, as well as the consumer, to identify prospects for development in the future, taking into account the introduction of innovative technologies.

Industrial enterprises have the necessary prerequisites, that is, resource potential, geographic location, technical capabilities, to carry out research, but there is no mechanism for not only developing but also managing the strategy. Therefore, it is advisable to implement at the enterprises of the management strategy of innovation, which will allow not only to manage the strategy, but will also ensure its implementation, on conditions that a set of interrelated measures is developed, an algorithm for action is created, and a sequence of development and application of innovative technologies is established to achieve the formed goals. The foregoing proves the expediency and necessity of researching the essence of the concept of "management of the strategy of innovation activity", the peculiarities of the implementation of the strategy management process, the identification of stages or the algorithm of the construction of the management process, the importance of using the system and mechanism for managing the innovation activity of the enterprise (MMIAE).

In the writings of Malceva S.V. [6] the essence, appropriateness of the formation and features of the use of strategic management of the IA are considered in detail. The strategy of management of the IA is considered as a set of actions, a set of rules aimed at using the mechanism of production of new products in order to meet the needs of customers, improving the image of the enterprise, organizing the application of the development strategy. The disadvantage of this approach is that the impact of environmental risks on the implementation of the strategy is not defined, there is no algorithm for managing the company's or company's IA.

development, development of innovative projects. The advantage of the above interpretation is the definition of the role of innovation projects in the implementation of the IA, the feasibility of attracting investment capital, but the need to adapt to the factors of the environment and eliminate the factors of the internal environment.

Dudar T.G. [1], Kozlovsky V.O. [2] also focused on the study of the essence of the concept of management of innovation activities and concluded that it aims at achieving the long-term goals of the enterprise, provided that planning, control, and stimulation of innovation processes are implemented. Accordingly, the authors focused on the mechanism of implementation of innovation activities in order to increase the level of competitiveness and not noted the possibility of changing the goals and directions of innovation development.

Another author analyzed the interaction of innovation management with innovation activity, as management studies the process of production of new products, the development and implementation of inventions, improving the quality of goods and their consumer values, meeting the needs of consumers, the relationship of the company with the markets of products [7, p. 5-6]. However, this approach is aimed at researching the process of managing innovation, rather than identifying the peculiarities of innovation and innovative development of business.

A different approach was observed by Lebedeva I.B. [5, p. 24-26], who, under the direction of innovation activity, understood the method or tool of applying innovative technologies, the attraction of innovations, the advancement to the market of improved products, as well as the unity of actions of public authorities in channeling funds to the development of the IA. Note that the author considered the management mechanism at the state-level for its innovative development and did not mention the peculiarities of innovation at the enterprise level.

In contrast to the previous approach, Shapiro S.B. [12, p. 42-46] conducted an analysis of the management of innovation activities at the enterprise level, the state. The basis of the activity of any enterprise is the use of the process of managing the IA in order to interest employees in the development of innovative technologies, raising the level of qualification. At the same time, the state should be interested in providing financial

assistance for the implementation of innovative projects. The advantage of the analyzed approach is to determine the appropriateness of training the personnel of the enterprise.

Kolinko N.O. [4, p. 12] argued that the management of the IA aimed at achieving various kinds of effects in the enterprise on the basis of the tasks performed, the coherent work of staff, the rational use of their own resources, the production of new or improvement of existing products. The advantage of the approach is to take into account the factors of the internal and external environment for the operation of the enterprise and the process of innovation, but the role of innovation strategy is not defined.

Despite the diversity of approaches to interpreting the definition of management of the innovation strategy, there is no single approach to its definition, the systematization of the influence of factors on the use of the strategy, the failure to take into account the volatility of market needs, the sequence of actions for the organization of innovation activities, the implementation of control over the implementation of innovations, the conditions of the enterprise development and the question remains as to the role and practical significance of the management process for the activities of industrial enterprises. Consequently, the results of the study expanded the meaning of the concept of "management of the strategy of innovation activity of the enterprise", since it is not appropriate to identify with other concepts (Fig. 1).

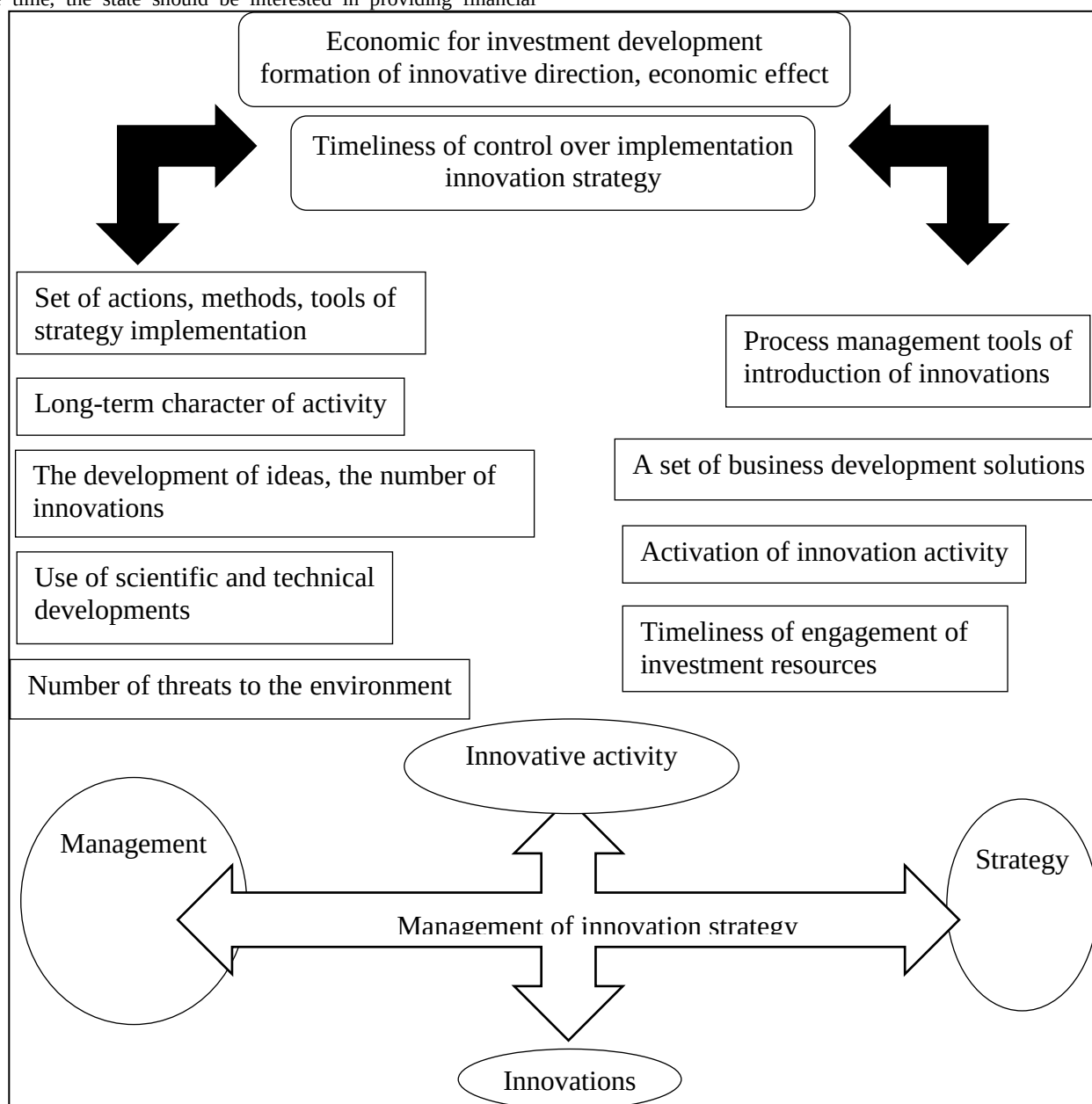


Fig. 1. Scheme of forming the essence of the concept of "management of the strategy of innovation"

Note: developed by the author

It is determined that management of the strategy of innovative activity of the enterprise is a process of strategy development, which includes methods, tools, means of management of innovative activity, covers the implementation of a strategy for resource use, innovation development, technology implementation, which will determine the prospects of economic development in accordance with the variability of the needs of the environment.

Conclusions. In the proposed definition, unlike the existing: there is the relationship in the direction of "management - strategy - innovations - innovation activity - management of innovation strategy", which reflects the combination of actions from the use of tools, the formation of a business model to the introduction of technologies, the production of new products and use of the algorithm for implementing the enterprise strategy; it is established that it is not advisable to identify this concept with the essence of the definition of the management of innovation strategy, the management of innovative development, since it is wider and covers the directions, goals, tasks of the IA, the peculiarities of organization and management of this strategy.

In the above definition, the strategy is considered not only as a set of measures, algorithm of decisions but also as a system of related actions, methods, tools, a set of rules that contribute to the assessment of environmental factors, the formation of strategies for protecting the strategy from their actions, the identification of innovation activities directions, the development of innovative technologies, the selection of innovations that should be implemented that will meet the needs of participants in innovation activities. At the same time, the system of interrelated actions are understood as follows: the definition of the goals of the organization; assessment of the internal environment; evaluation of the feasibility of a new product; sequence of innovation implementation; the procedure for implementing the strategy of innovation activity; interaction of participants in innovation activities and coherence in the adoption of managerial decisions; control over the process of management and implementation of the strategy. The choice of a more effective strategy is also provided by a management process that facilitates comparisons of several strategies, assessment of the factors affecting them, the implementation of the chosen strategy, identifying a set of actions that will allow the use of innovations, and establish enterprise activities.

Achievement of the economic effect from the implementation of the process of managing the strategy of enterprise IA depends on: determining the sequence of implementation of the steps necessary for the realization of the strategy; construction of an algorithm of

planning, organization and management of the strategy; determining the factors of the external and internal environment that affect the IA; development of methods of protection against the risks and methods of competitive struggle; adjusting the goals of the activity; search and introduction of innovative technologies; realization of scientific researches and development of innovations; making calculated management decisions.

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THE INNOVATIVE DEVELOPMENT OF QUALITY MANAGEMENT

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Abstract: *Smart Products have information about their manufacturing processes, management of their quality, future application and recycling. They actively support the production processes (when they will be produced, with what parameters, with what materials they should be produced, where their quality control should be located, when, what modifications, etc.). In these conditions, quality management should meet new requirements imposed by the fourth industrial revolution.*

KEYWORDS : *Industry 4.0, Quality 4.0, intelligent products, quality management*

Introduction

Industrial development passed through different stages of development or the so-called. Industrial revolutions. The first industrial revolution is related to the mechanization driven by water and steam. It was followed by the second industrial revolution, mass production (Ford, Taylor, etc.) with the help of assembly lines and the use of electrical energy. The third industrial revolution is the digital revolution characterized by the use of electronics and information technologies to further automate production. However, the increasing complexity of the products, new requirements for production and quality management are set, which are the heart of the fourth Industrial Revolution (Industry 4.0).

I. Requirements of Industry 4.0

The factors that impose these changes are: increasing flexibility requirements, resource efficiency product customization, integration of customers and suppliers in the designing and production process, reorganization of the value chain of production processes in the global market.

The following questions are standing:

- How do you integrate the production data and all the quality data that is attached to it in the new digitized business processes?
- What is the current state of Industry 4.0 development and how will it affect the industry?
- Why should quality management also be reinvented and what safety aspects should be considered?
- How Automated Quality Management Systems (CAQ) will be developed to meet Industry 4.0 requirements in the near future

II. Intelligent Factory (Smart Factory) and Innovative Development of Quality Management

Structure of Smart Factory. An important element of the fourth Industrial Revolution is the Smart Factory. Quality management is an important part of the future intelligent infrastructure function [1] Smart Factory is defined as a factory where there is independent communication between people, machines and resources in integrated network to perform production tasks. These systems perform their tasks based on the information coming from the physical and virtual world through the

Internet of Things (Components) and the Internet of Services [3].

Physical world information is a real position or state, unlike the information of the virtual world, such as electronic documents, drawings, simulation models, etc.[9,11]

Quality 4.0 is a reference to Industry 4.0. The fourth Industrial Revolution is happening around us at the moment. The digital impact of it is expanding and uniting it with the physical and natural world. Several critical technological changes have been allowed, including big data, analysis, connectivity, scalability and collaboration. It connects people, machines and data in new ways, creating an adequate environment, leadership, cooperation.

Historically, the notion of quality assurance through control at the end of the production process today has changed to the concept that the quality is planned, created and provided to the production of the product or the supply of the service. The optimization of quality planning processes, the introduction of preventive actions reduces errors, reduces costs and achieves greater efficiency in value. As a result, new management methods and concepts of production control are developed and implemented, through quality assurance and total management of customized products[5].

According to a number of studies, for example the Stuttgart Quality Management Institute, the highest proportion (70 per cent) of discrepancies occurred at the product planning stage and the highest proportion to remove inconsistencies (80 per cent) was in the production stages and sales shown in Fig. 1 [8].

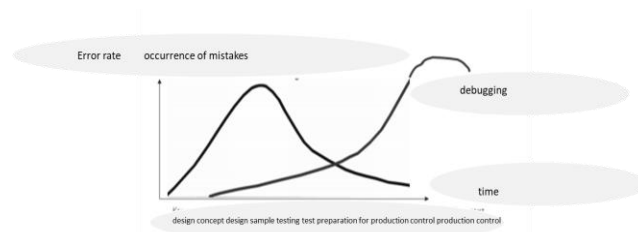


Fig. 1. Creating and removing errors in stages of product development

Each manager should have knowledge to create the quality as well as the social and didactic-methodical knowledge of their distribution in the company. Because of this reason, the interest in quality is constantly increasing in theoretical and practical terms.

Quality management occupies a significant share in various sciences, and it is actively presented as a subject of contemporary empirical interdisciplinary researches and has an important role in the field of economic science and management theory.

In a study in 2017 of the Bulgarian Chamber of Commerce and Industry (BCCI) about 500 companies have expected to increase their export revenue but only 37% actually did it [10].

The most common questions for quality managers:

- Are the certifications based on ISO, CMMI, etc. going to be sought?
- Does the quality take a new meaning in Industry 4.0 organizations?
- What kinds of trainings should quality managers get so that they can prepare for rapid changes in their organizations (or their customers' demands)?

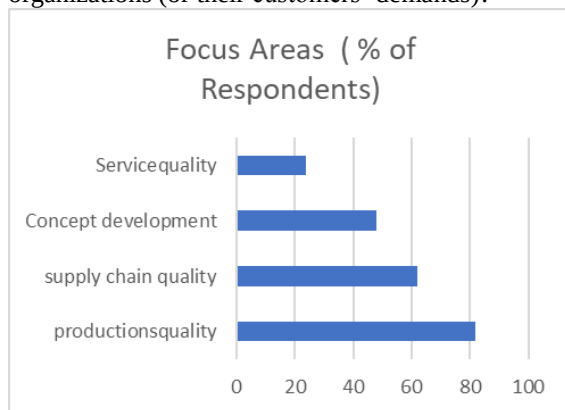


Fig. 2. Focus Areas of quality problems

Quality is not limited to the manufacturing process. To achieve the highest quality, it must already be created in process of designing. 82% of respondents say that production quality plays a big role in their business, but in contrast, only 48% say their quality management also is focuses on the concept definition phase.

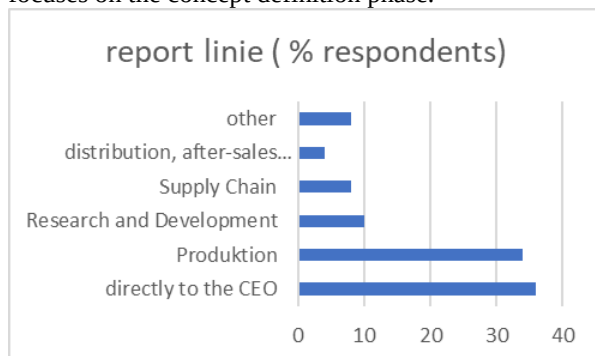


Fig. 3 QM Report Direction.

The prospects for the companies surveyed are good. They can easier move to information services and software systems. This opens new opportunities for regional firms, which also will be able to integrate internationalization processes. In every case, these companies will benefit from the interdisciplinary transfer of knowledge and technologies. Currently, many companies use CTI-typical technologies such as cloud services, etc. In addition 90% of the interviewed

companies have reliable WLANs. Discussions made it clear that currently that clouds are very important part of the modern companies.

Technology related to Intelligent Factory - IoT, big data advanced machine learning reality, and so on - can be used to improve quality.

III. Challenges to Quality 4.0.

On the basis of the conducted studies, the requirements of Quality 4.0 can be outlined in the different stages of the product life cycle:

- / design / design stage

In the past, "quality" is usually associated with production processes - used raw materials, assembly, finishing and packaging - but quality must be an integral part of the concept / design / design phases.

- At the control and service stage

By collecting and getting the sense of user data from the field, future failures can be prevented with minimal loss of material. The time it takes to identify inconsistencies can be extremely short, thus ensures customer satisfaction.

IV. The Role of Human Factor and Company Culture in Quality 4.0

Quality 4.0 has broad scope of business, and companies should strive to inspire a quality approach as part of the overall corporate culture[1,2,7].

The use of sensors to collect data for root cause analysis, diagnostic techniques can be performed remotely. By collecting feedback from a number of devices, it can also be used as a method for further analysis of machine behavior or product performance.

Conclusions

The following conclusions can be made:

- Ensuring Quality 4.0 is one of the most important key factors for successful implementation of Industry 4.
- Unified frameworks and standards need to be set up at an early stage to make industry ready to invest. This is necessary to examine the individual quality issues in more detail and to further explore through detailed technology impact assessments.

Quality management must be in constant optimal relation to the functions of the production cyber-physical system. • Quality management is radically altered and qualitatively different from the existing one, with the information component (stream) being entirely virtual in cloud boundaries, allowing free real-time communication with Smart-Cyber system

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CORPORATE LIFE CYCLE AS AN INSTRUMENT OF ITS GROWTH MANAGEMENT

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The key problem facing all enterprises is that of survival. Corporate life cycle theory is an important tool for the survival and development of business entities based on value changes affected by external and internal environment shifts. It gets an enterprise to rethink its existing values, organization itself, production process, scale of production, business structure, mechanism of adaptation to environmental changes, resources acquisition, flexibility and manageability formation, as well as of personnel and external stakeholders systems' relationship. Understanding the specifics of the main corporate life cycle stages allows to avoid numerous mistakes in its development and predict typical growth problems. Awareness of the mentioned specificity makes an enterprise to think about the management system before the problems take place. Life cycle analysis enable problems structuring faced by an entrepreneur or a manager.

Adaptation of the biological cycle concept in management led to the formation of corporate life cycle theory developed in the studies of I. Adizes, L. Greiner, K. Cameron, R. Kahn, D. Katz, J. Kimberly, R. Queen, F. Liedtke, D. Miller, B. Scott, W. Torbert, P. Friezen. Ukrainian scholars like Y.S.Primush, S.V. Koryagina, T. Malajeva, S. Dovbnya, Y.S. Shembel, A.M. Shtangret, O.I Kopylyuk, O.Y. Kuz'min, O.G. Mel'nik and others also conduct research in the field.

According to this theory, the life cycle is the period when an enterprise essentially changes its values and attitudes, graduating several successive stages of its development, which determine the peculiarities of managerial tools corresponding to the period of enterprise performance. It should be noted that changes in value orientations and objectives based on external and internal business environment changes are the main reasons of enterprise cyclical development. The changing external environment factors make enterprise to adopt to these changes, rethink the existing values, organization itself, production process, system of staff and external stakeholders' relationship.

A range of issues associated with the corporate life cycle is quite wide: number of stages, causes of cycles, changes in the various business characteristics during life cycle's stages, stages' sequence and duration, opportunity to diagnose a particular life cycle stage, application of managerial mechanisms at different stages of its development, etc.

Researchers like T. Y. Bazarov, T. Zheleznyak, J. Kimberly, D. Miller, B. Scott, P. Friesen, when building the model of corporate life cycle, characterize in general its position at certain stages of growth. They describe scale of production, business structure adjustments, rate of return and other aspects of activities.

In other models, scholars use a specific criterion as the basis of division into stages of growth, namely:

- Corporate growth is considered as one affected by the particularities of business structure and its changes (L. Greiner, D. Katz and R. Kahn);

- Corporate growth is closely related to the group cohesion. The model describes natural sequence of stages to pass through, specifies the mentality that determines each of them (W. Torbert);

- Corporate growth depending on each stage's functional problems - the problem of adaptation to the environment, resources acquisition, goals achievement and patterns of behavior promotion (F. Liedtke);

- Concentration on two key parameters of corporate life: flexibility and manageability (I. Adizes);

- Enterprise graduates through stages of its life cycle. Different emphasis and tasks at different stages cause various performance criteria (R. Queen and K. Cameron) [1; 2].

Larry Greiner was one of the first who proposed own theory of corporate life cycle. He substantiated that an enterprise which operates in an industry consistently goes through five phases of growth: growth through creativity, growth through direction, growth through delegation, growth through coordination and control, growth through cooperation [3].

The characteristics of corporate life cycle phases by L. Greiner are presented in Table 1.

According to the scholar, each stage of corporate growth has two phases: evolutionary development and revolutionary development. In the period of evolutionary development, enterprise evolves continuously, without significant leaps, in contrast to revolutionary development, when enterprise suffers internal conflicts caused by tasks and management style disparities. This initially leads to output drop and deteriorating financial position. The management is charged at the stage of revolutionary business growth to choose and implement quickly new managerial tools.

Analysis of corporate growth stages by L. Greiner indicates the following limitations of the model:

- firstly, the size of an organization is the determining parameter of its growth: small enterprises' strategy does not require significant increase in its size, and they do not face some stages and crises;
- secondly, the model does not describe the development of an enterprise but of its management system;
- thirdly, the author himself did not determine what is the final crisis of the fifth stage of evolution.

Table 1 Characteristics of corporate life cycle phases by L. Greiner

Life cycle phases	Stage details
Growth through creativity	Own product design and market boundaries identification. Rapid business growth. Leadership crisis. Growing employees number. Formalized management structure. The owner sets rules, priorities and principles of work. The expediency of hiring a professional manager.
Growth through direction	Stable sales growth, expansion of management, more compound organizational structure of an enterprise. Centralized management. The crisis of autonomy. The need to approve decisions with top-management. Managers cannot make decisions on their own, which impedes business development.
Growth through delegation	Responsibility is given to the middle managers. Capturing new markets, product assortment expansion. Profit centers and bonuses are used to motivate employees. Acquiring outside enterprises that can be lined up with enterprise units structure. Crisis of control. Autonomy of employees lead to decisions not approved by the top management. Introduction of more rigid forms of control and reporting.
Growth through coordination and control	Sales growth. All decisions are consistent to corporate mission and general goals of management. The risk of any mistake is minimal. Strengthening control in big business. Decentralized divisions are merged into product groups (producing homogeneous group of products). Formal planning procedures are introduced and intensively improved. The number of top managers is being increased. Increase of control. Every product group is treated as an investment center. The border crisis. Lower overall innovativeness, flexibility and speed of decision-making.

Growth through cooperation	The focus is on solving problems through team action, staff experts at headquarters are reduced in number, formal management systems are simplified, increased number of discussions in the form of open conferences, educational programs are used to train managers at an enterprise. Project and consulting teams' formation, training programs. Creation of information management systems. Economic rewards are geared more to team performance.
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Source: compiled by [1]

The model of I. Adizes is widely spread in science and practice. It includes the following stages: courtship, infancy, go-go, adolescence, prime, stability, aristocracy, recrimination, bureaucracy, death [4]. The model develops the theory of L. Greiner and complements its methodology of diagnosing various problems and their elimination.

Professor I. Adizes believed that every corporate life cycle stage ends with a crisis, and it is necessary to consistently solve the problems that arise, caused by business growth, competition, technologies and environment changes. He noted that corporate crisis are the result of predictable problems, which can be divided into three groups:

1) typical problems of adolescence (or "disease of adolescence");

2) abnormal problems;

3) pathologies that the company cannot solve by itself.

The scholar noted that if an organization does not solve regular problems, they become abnormal and eventually turn into pathology. The aging phase begins. Besides, if an enterprise ignores negative changes during its downturn, or management failures, it can lead to its death. An enterprise loses its ability to provide effective business and market share; it may become bankrupt and pass to the stage of death. However, I. Adizes points out that after the downturn phase, there are two ways of growth: recovery or bankruptcy.

Corporate priority values for different life cycle stages are presented in Table 2.

Table 2 Corporate priority values in the context of I. Adizes' life cycle model

Stages	Organization	Management	Staff	Capital	Consumers	Policy
Courtship	++	++	++	+	++	-
Go-go	-	-	-	-	+++	-
Infancy	-	+++	-	-	++	-
Adolescence	++	++	-	-	++	-
Prime	+	++	+	+++	++	-
Stability	+	+++	+	+	+	-
Aristocracy	+	+	+	++	-	-
Recrimination	-	-	-	++	-	-
Bureaucracy	-	-	-	-	-	+++

Source: compiled by [4-7] Note: +++ – the most priority values; ++ – quite priority values; + – priority values; - – absence of priority values.

Deteriorating key financial indicators represent one of the first symptoms of corporate aging, which indicates pathological problems at the early stages of aging (stability, aristocracy).

Profit orientation prevails throughout the downturn. Due to the predominance of investor interests in comparison with the consumers' interests, the return on investment gradually plays increasingly more important role than the return on sales. At the aristocracy stage, the return on investment becomes a priority goal. Indicators of the return on sales and turnover lose their significance. The corporate future of an organization, which loses its competitive advantages, depends mainly on investors. Thus, indicators like the return on equity, financial soundness, liquidity and solvency, which often have inadequate values, are of key importance to measure entrepreneurial activity at the recrimination stage.

The main financial task at the final stage of a life cycle (bureaucracy) is to receive disbursement to artificially support corporate performance.

Table 3 illustrates the priority values at the growth and ageing stages.

In order to recover, an enterprise needs to make radical changes in all fields of its activity. To cope with the crisis, it is not enough to cut business costs and jobs. There has to be a comprehensive program of business growth. If an enterprise is able to provide restructuring and modernization, then it can survive and continue to exist [8].

Solving complex tasks during the recovery stage is possible by the newly appointed managers' team. However, according to I. Adizes, new top management helps an enterprise to skip aging, only if it changes the system (organizational structure, remuneration system, information system, etc.) [4]. To increase business flexibility, it is important to motivate managers and staff initiatives. It is possible to launch new units. The development of new products makes it necessary to upgrade technology and equipment. During the recovery period, the problem of employee adaptation to organizational changes is a topical issue. There has to be employees' loyalty to management activities, commitment to long-term goals and preparation to deal with temporary difficulties. The main purposes of this period are business recovery and bailout.

Table 3 Priority financial indicators at the corporate growth and ageing stages

Stages	Investment	Liquidity and solvency	Turnover	Return on sales	Return on equity	Financial soundness
Courtship	+++	-	-	-	-	-
Go-go	-	+	-	-	-	-
Infancy	-	+	+++	-	-	-
Adolescence	-	+	++	+++	-	-
Prime	-	+	+	++	+	-
Stability	-	-	+	+	++	++
Aristocracy	-	-	-	-	-	+++
Recrimination	-	+	-	-	+++	+
Bureaucracy	+++	-	-	-	+	-

Source: compiled by [1; 4; 5]

Note: +++ – the most priority values; ++ – quite priority values; + – priority values; - – absence of priority values.

CONCLUSIONS

The life cycle concept gives the opportunity to structure problems that an entrepreneur, an owner or a manager face. The life cycle models allow to predict development and critical situations, therefore, they enable their thorough preparation. These models describe in detail what is going on within an enterprise, thus revealing principles, natural phenomena and deviations, which help managers to focus on the problem solution.

Despite the differences in life cycle models, it is obvious that business characteristics vary at different life cycle stages, which requires application of various management methods. Studying corporate life cycle allows to consider business entity as a dynamic, but not static institution and to approve timeliness in decision-making aimed at its growth.

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TRANSPARENCY IN THE LIFE CYCLE MANAGEMENT OF FINANCIAL INSTRUMENTS OF INDUSTRIAL PRODUCTS

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Summary. The specificity of lifecycle management of industrial products as a set of activities that are coupled in a certain way over time and space require an appropriate organization for its development and control. In this sense, companies must have such an organizational attitude that stimulates and implements an appropriate policy that provides competitive advantage and high efficiency. Essentially, this means well-established network linkages and functional links at all organizational levels and all units. This organization is a set of relatively stable relationships that exist between its components. It is a means of transparent management through which the goals, strategy and policy of the companies are realized. The purpose of this article is to explore the process of managing the life cycle of industrial products using financial instruments.

Transparency in product life cycle management.

Firms themselves determine the way they operate and develop according to market requirements and formulate their goals, defining and realizing relevant development priorities. Thus, they organize transparency in their activities, taking into account the organizational conditions and the impact of internal and external factors. In this context, it is of paramount importance to create conditions for the transparency of the life cycle of the industrial product in its management with financial instruments. This is particularly typical and necessary for industrial products that refer to the category of tangible assets. Thus, different valuation approaches are used to determine the value of industrial products that have the nature of tangible fixed assets. All of them, however, are related to the asset's cost of production and it changes throughout the product's life cycle. It has different factors at different stages in its formation, but not all are taken into account in its assessment. All evaluation methods are tailored to evaluate it after login in operation, without taking into account impacts when it was produced but not yet in operation (storage time).

It has been shown that industrial products have the strongest influence on the following groups of factors, which have a certain interrelationship with each other;

- Physical waste, which begins after the product has entered service.

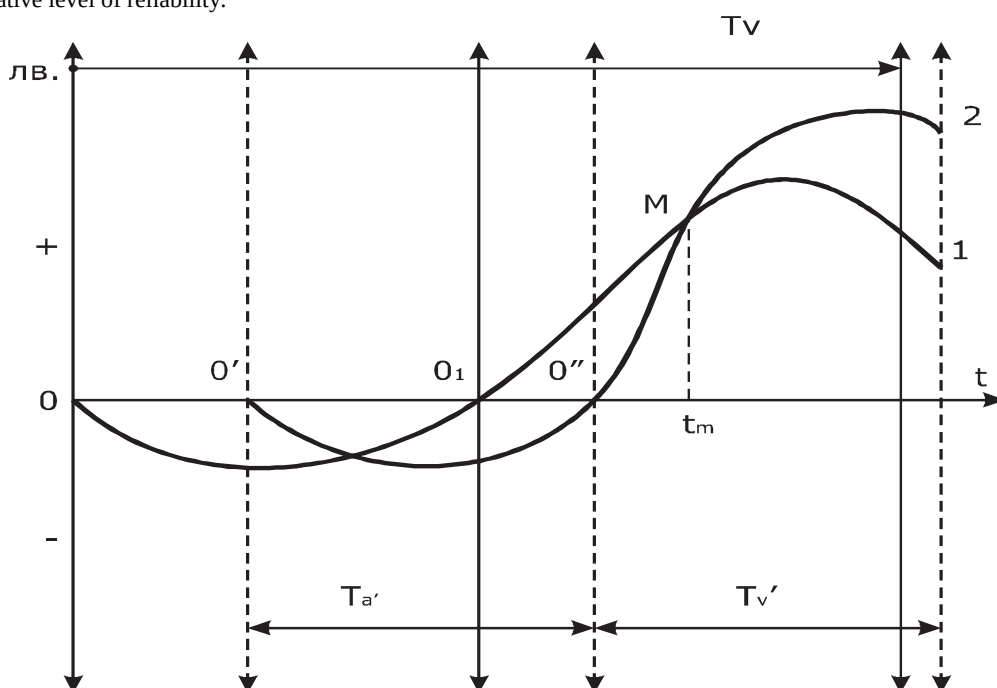
-Innovation aging that affects throughout the product lifecycle from start to finish. It leads to the search for approaches and ways to shorten operational life, to extend the warranty period and to increase the normative level of reliability.

-Economic devaluation with globalization and high technology is creating an increasingly dynamic development environment. This in essence means that this indicator will play an increasing role in the future and more and more assets and industries will depend on it. The most commonly used assessment approaches are currently: revenue, cost and market. When applying the different valuation approaches, a discount factor is applied that reflects the movement of money over time. This process is strictly regulated, both normative and factual. After the asset is released, its amortization or accrual of depreciation charges is initiated, which presents different risks. Differentiation methods are used at different stages of the product's life cycle. This toolkit can also serve as an attempt to methodologically summarize the individual discounted methods that can be used at different stages of the product's life cycle.

Characteristics and stages of the life cycle of an industrial product.

The life cycle of the industrial product is its main feature, which characterizes and represents the period from its origin to its sunset. In this case, an industrial product that includes two models is considered. In this case, the model will only mean design changes without altering the main technical performance of the product such as performance, weight, gauges, etc.

Or these are the main indicators whose change leads to innovative aging of the old product to the new one. The life cycle graph of such a product with two models is shown in Figure 1 and is shown in a bulk without the individual stages of the cycle being indicated.



where:

t - time

T_a, T_a' - investments, including the idea, study, design and production stages of the 1st and 2nd industrial product model.
1 and 2 models

T_v, T_v' - including development, realization, maturity and aging for 1 and 2 product model.

M, t_m - innovative innovation aging for the 1st model

At sunset for the industrial product is meant not a complete depletion of the product's lifetime resource, but aging has resulted from new design solutions that are better designed and improved. A distinction should be made between the life cycle of the first model and the life cycle of the second model. For one product we can have several successive model solutions. In addition, the life cycle of the product as a whole is a concept that expresses the change in sales and profits from product creation to market marketing. However, they have many common ground. For example, in innovation aging of the innovative solutions set in the product, there is a drop in sales due to a partial loss of competitiveness.

Receiving data during work in a highly automated information environment opens up new opportunities in the field of services related to the use and service of the product. Conditions and the opportunity to make unified, accurate, accurate information solutions at every stage of the product's life cycle are created.

Managing the life cycle of the product.

In the case of product lifecycle management, the industrial company manages all information in real time using information technology. The goal is to provide the relevant information at the right time and scope, thus requiring comparisons of market, consumer, company and regulatory requirements, benchmarking and more.

The concept of lifecycle management of an industrial product (asset) is important in:

- developing new products as the life of innovative products is short and the development of a new product requires ever greater investment;
- building an efficient product and technological structure of the companies;
 - the complex study of innovative solutions for the past and future, which would provide a rich information base for evaluation and prognosis of product and technology prospects.
 - Discontinuous processes in these conditions - risk.
 - Economy of development of these processes.

It is therefore important not only to examine the life cycle of the industrial product, but also the possibilities for its management with financial instruments, requiring full transparency of the life cycle of the product (asset).

To analyze the theoretical basis of the discount processes in estimating the revenues and expenditures under the conditions of rapid innovation aging.

To study the factors that affect the level of cash flows - species, nature, impact strength

Look for alternative solutions to eliminate the harmful effects on the estimation of the forecasters that form the value of the cash flows.

To examine the discount processes in these conditions and to determine the magnitude of the risk, etc.

Explore the patterns of development of these processes

Particularities of cash flows in the context of the rapid innovation of aging of tangible assets.

Cash inflows in the context of fast-moving aging of material assets influence various internal and external factors. Influencing external factors are innovation aging and internal regulations, state policy, and so on.

The manifestation of properties of rapid innovation aging manifests in the current and future value of the material asset. Thus properties of the present value in the context of alternative solutions against rapid innovation aging and in the case of planned aging can be managed with financial instruments. A particular role in this governance process will be played by discounting definitions such as discounted cash flow, cash flow, nature of the financial instrument, peculiarities. Discontinuous processes in these conditions of uncontrolled risk, the regularities of the development of these processes through the different stages of the life cycle.

Discontinuous processes in estimating revenue and expense under the conditions of rapid innovation aging.

The factors that influence the level of cash flows determine their type and nature can also be divided into internal and external, Alternative solutions for eliminating the harmful effects on the estimation of the forecast elements forming the value of the cash flows can be taken internally.

Based on the life cycles of the different products, their interaction and a complex impact on the main economic indicators, it is deduced that the company provides resources and the dynamics of the company's development. At any given time, companies must maintain a dynamic balance between opportunities and reality, to take the production of the old products in a timely manner, to maintain the maximum volume of production of those products that provide high efficiency and to carry out the necessary research and engineering developments for the creation and introduction of new products in production. The life cycle of an innovative product is given in Figure 2.

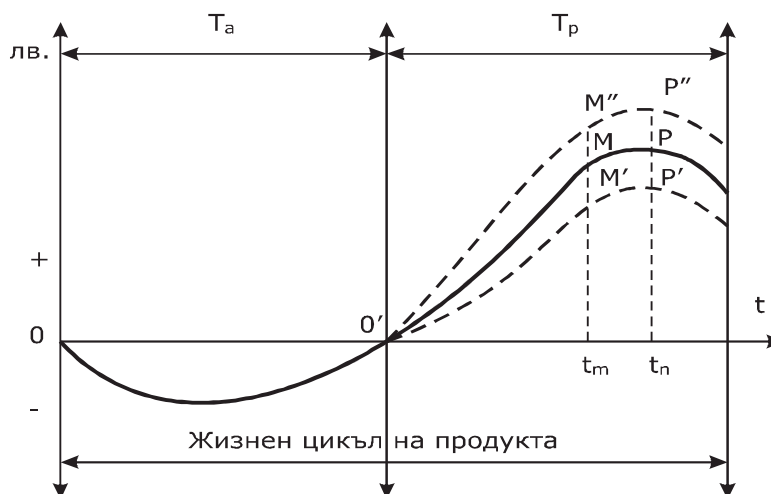


Fig.20. Life cycle of an innovative product

where:

t - time;

Life cycle of the product, including its production;

T_r - sales;

1 - cash changeover curve where investments are invested during periods of time and in the period of return are reversed with the profit;

M, M', M'' - emerging innovation aging at time t_m and points P, P', P'' - change of profit.

In the life cycle of the product, we have a change in the time span ($t_m - t$), which is derived from the effects of various factors. This decline is for both sales and profits. This means that even after the innovative aging of the innovative product in you, the sales and the profits for a certain period of time continue to grow, with the decline only after R, R'.

This is due to the impact of various internal and external factors, such as the conservative nature of consumer taste, advertising, market specificity, etc. Despite the impact of these factors, the product's life cycle has already exhausted its resource and the company should create new innovative products.

The life cycle curve consists of a development cycle and a market cycle. The market cycle covers product entry time, growth, maturity and declining sales.

The stages of the life cycle of an industrial product and its characteristics are reflected in Table 1. For individual companies, they may vary according to the specific objectives, resources and competitive environment of the company

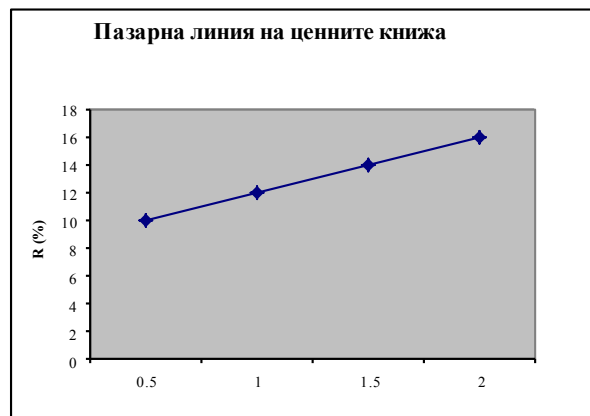


Table 1. Life cycle stages of an industrial product

Criteria	Stages of the life cycle of an industrial product				
	Development of design, production	Introduction	Growth	Maturity	Decline
Competition	One product		average	Strong	Small
Users		Innovators	Serial Market	Serial Market	Reduction
Product assortment	Two models	One model	The number is growing	Full assortment	Save
Sales		Depends on the conditions	GrowGrowss	Grows	decreases
Profit		Small	Нарастват	High	decreases
Strategy	Designing a new product	Experiment of the new product	Zero Series	Sales	

In fact, one product may have more than one model, and their life cycles usually do not match the life cycle of the product. The product may also have innovative obsolete elements and designs or innovative elements whose life cycle is even higher even after **Summation Method**) се описва от следната обща формула:

$$r_e = r_f + \sigma_r + s_r$$

the innovative product aging, the product to mark a market downturn but some innovative elements in it are at an early stage or in growth respectively

Formation of a discount factor as a financial instrument to derive the market value of tangible assets.

When estimating the market value of tangible fixed assets, different valuation approaches are used. When applying the different valuation approaches, a discount factor is applied that reflects the movement of money over time. This process is strictly regulated, both normative and factual. After the asset is released, its amortization or accrual of depreciation charges is initiated, which presents different risks. The measurement and evaluation of the degree of risk includes;
The method of accumulation (risk-build) proposed a decade ago by James H. Schild and later extended to specific cases by **Shannon Pratt** (Summation Method) is described by the following general formula

$$r = r_f + \sigma_r + s_r$$

r_e - expected rate of return:

r_f - risk-free rate of return:

σ_r - the general risk margin:

s_r - the specific risk margin:

One of the commonly accepted methods of measuring the overall risk of an investment is to calculate the standard deviation of risk from the average.

$$\sigma = \sqrt{\sum_{i=1}^n (R_i - R)^2 p_i}$$

$$\sum_{i=1}^n p_i = 1$$

Where p_i is the probability of occurrence of this condition.

Each discount rate, regardless of the method of its determination, includes the following three relevant elements:

1. Return on risk-free investment.
2. A risk premium that expectations of return on the capital market in general - one of the most stable elements of the norm.
3. Risk specific risk that depends on the particular company. For companies with a lower risk than the capital market, it can also accept a negative value.

THE CAPITAL ASSET PRICING MODEL (CAPM) FOLLOWS THE USE OF FACTOR B FOR RISK MEASUREMENT:

$$r_e = r_f + b \cdot (r_m - r_f)$$

r_e - expected rate of return:

r_f - risk-free rate of return:

b - Systemic risk:

r_m - average market return:

$(r_m - r_f)$ - the total market premium.

The above formula gives the formal relationship between two variables by which the model determines the cost of capital assets as their function:

1. The Required (Required) Rate of Return (RRR),

The risk consists of a systematic and non-systemic component. The systematic risk measure is the coefficient of the linear regression equation β , the value of which represents the return of a single share versus the return on the whole market and reflects the market sensitivity of a share. The average value of b of all shares is 1.0. If a share with a higher rate of return on the market is more risky, ie it will fall more at the same rate of decline in the market. From a mathematical point of view there is no upper limit for β , the lower is 0. For most actions, the value of β ranges from 0.5 to 1.5.

The risk premium for a share will be determined by the product of the total market risk premium for equity and the corresponding b . To assess a particular b , data from the relevant branch is used. If a market is missing, data on the share of other companies' shares in the particular branch is used. The cost-to-income (R/E) relationship is formed, and then an analysis is made of whether the enterprise is more or less risky to find its place in the line of business in the branch.

The theory of the model is based on the following three idealized assumptions:

- Smooth market - ie. complete, completed market (without friction), in which each asset is completely detailed and each person can buy individual details of these assets, there are no taxes, no information costs and there is a great deal of demand and supply, so the individual can not influence the price:
- rational behavior - everyone acts on a rest that will give him maximum wealth and reduce the risk, so everyone is very well informed:

- homogeneity of expectations - all people have fully matched expectations in terms of predictable revenue.
- shares, or do not have shares at all on the market, bits can not be measured directly. However, there is a significant correlation between b and the risk that can be calculated from companies' financial statements. Because the non-systemicity component of the risk (not reflected in b) is too important for components that are not public, do not have shares in the market,

the risk analysis part of the financial condition analysis is a very important part of the assessment process.

Determination of the discount rate (rate of return)

The discount rate (rate) for bringing a sequence of net cash receipts to a value at the present time can be determined by the Weighted Average Cost of Capital (WACC), the Capital Asset Valuation Model (CAPM) the method of risk, the dividend yield method, according to the Gordon model and the Arbitrary Pricing Theory (ART).

This methodological toolbox provides the opportunity for financial impact and control over the stages and lifecycle of the product.

Conclusion

On the basis of the above, the following conclusions and summaries can be made:

Managing the life cycle of an industrial product (tangible asset) can define transparency across all product cycle loops. The use of financial instruments is a successful approach to management and control not only of the individual stages of the cycle but also an informational possibility for interim and prudent valuation of the asset.

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BASIC CHARACTERISTICS OF THE SOFTWARE PRODUCTS AS A FACTOR FOR STRATEGIC SUCCESS OF THE COMPANY

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Abstract: *This paper is aimed at defining the basic characteristics of the high-tech products, which are the most important factor for strategic success in the high-tech industry. These products differ from products in other industries in many ways, but the most distinguishing features are related to their advanced technology, a relatively short product life cycle and the high level of innovation. Developing business models and strategies managers should avoid thinking that high-tech products are products above all and they can apply the same approach in managing business. They should be fully aware of the distinguishing features of the high-tech products, so to be able to develop and implement successful business strategy in the long run.*

KEYWORDS: HIGH-TECH PRODUCTS, BUSINESS MODELS, PRODUCT STRATEGY, MARKETING STRATEGY

1. The main features of high-tech products

Nowadays we witness the rapid development in any businesses, but the most prominent is in the field of high-tech industry. ICT including, blockchain enables the managers to guide business and give them more options in this distributed microenvironment by introducing clear and highly customizable framework to connect them all. In addition, all information, which is saved on the blockchain, is immutable and transparent for everyone. The technology promises real-time information about the most important KPIs of all the participants [1]. Companies must be able to respond quickly and effectively to change, such as when dealing with new quality problems, rapidly declining prices, or subtle but steady shifts in value from hardware to software and services. The best way to survive and thrive in such an uncertain, competitive world, particularly in an age of technological disruptions as well as economic globalization is to focus on understanding in details the product characteristics that will enable managers to find the best way to prepare the company to perform well over years and decades [2,8]. This means that they should be able to distinguish short-term tendencies in management thinking from long lasting principles, which are closely related to the nature of the products, that can help them to create value for customers in the long run.

To support ease of reading this paper we will generally use the term “software products” instead of referring to software-intensive products and services as well. The term software product management covers not only software products, but also software in software-intensive systems and services. These products are often intended for specific markets and belong mostly to the industries such as biology, telecom equipment and information, electrical equipment, automotive, aerospace, and energy. Software differs from products of other industries in many ways and they require large investments in research and development [7].

The term “high technology” is a contemporary category that includes any product manufactured with some type of an advanced technology, not only from shoes to long-range missiles, but also can be applied to many categories of services. In the literature, there is no a clear definition for high-tech products but the main finding is that a technology is not the only characteristic and distinguishing feature of these products. According to some authors high-tech products can be described as follows:

- They need sophisticated technology;
- They are changing and updating frequently;
- They are new for the markets;
- They involve high research and development investment;
- They are for specific markets;
- They are integrated into high-tech applications [4,10].

Having considered the above mentioned characteristics, as the most important can be pointed out three of them, namely incorporation of sophisticated technology, a relatively short product

life cycle and the integration of innovation. Products should also be differentiated as simple components or complex systems and according to their degree of standardization or customization. Last but not least characteristic of high technology products that worth to be mentioned is the fact that public sector has strong influence, either directly, through governmental research programs, or indirectly, through the military budgets.

2. The specifics of high tech product business strategies

These differences have a significant impact on the contents of a software product’s business strategy. According to the literature organization’s strategy describes how it intends to create value for its shareholders, customers and society as a whole. The key challenges stem from the fact that strategy is tightly related to three dynamically changing factors, the lack of data needed for one to choose how to reach his/her goal – “ignorance”; the “incommensurable” business context, and the “indeterminate” people, who are sometimes “unpredictable – and creative”. These factors fall in the overarching category of “knowledge absence” [5]. Software product managers are responsible for developing the strategy for the products and for implementing and updating it over time. A strategy covers a time span of about one to five years but it largely depends on the product’s context, i.e. domain, technologies, and market segments. The product strategy describes how the product is supposed to evolve over this strategic timeframe. There is no difference between high-tech products and other industries in respect of the management objectives. The primary aim of software product management is the same as those in other industries - to achieve sustainable success over the life cycle of the product. This generally refers to economic success, which is closely related to the generated profit margins. The role of product manager is also the same. He has to plan and keep track of the business aspects. They should make decisions concerning long term perspective and if the losses related to an investment phase will be followed by a rise in the profits in the next phase, a longer-term perspective is appropriate. They are responsible for applying the most suitable business model, which can lead to sustainable development of the company. In the literature, a business model is described as the rationale of how an organization creates, delivers and captures value by interacting with suppliers, customers and partners. A business model describes which products and services are offered by a company, and how revenue streams relate to the different products and services. It is often considered at the corporate or business unit level, but its consideration can also make sense on a solution level that spans multiple products and services or on an individual product level. There are different classifications of business models according to different dimensions. The most important can be attributed to the: types of products/services provided, business model archetypes used and revenue streams [7,11].

According to the former criteria, types of high-tech products/services can be financial products (cash and other assets), physical products (real, physical products, durable and non-durable goods), intangible products (software but also other intellectual property, knowledge and brand image) and human services (people's time and effort).

The latter criteria (Business Model Archetypes) is described in the literature as a basic patterns of doing business. There is no difference in software product industry and the archetypes are as follows: creator, distributor, lessor and broker. In general creator uses supplied goods and internal assets and transforms them to produce a product that can be sold to the customers. The main work that creator should be done is designing the product. For an example of creator can be pointed out Apple who designed the iPod. The main function of distributor is to buy products and to resell the same products to customers. Illustrative examples are companies in the wholesale and retail industries, like Sears or Saks, or stores that sell shrink-wrapped software. A lessor provides the temporary right to use, but not own, a product or service to customers. For instance landlords, lenders of money, consultants and software companies that license their software to customers. For human services, HR lessors lend their employees' time to customers. A broker facilitates the connection between potential buyers and sellers. A broker don't have ownership of the products and services. An example is a stock broker. In the context of software products the example is Google's advertising business, which matches the advertiser with potential customers.

In the practice of high-tech industry a business model is constructed by choosing and combining one or more of these three business model elements. Products and services can be offered standalone, or they can be offered as a group of them. For example of a such combination can be considered software vendors who are typically offering intangible products and act as a creator and lessor of software, but also offer human services like consulting, maintenance and support. A cloud business model not only offering a service to the customer, but also has the software vendor who act as a creator, a lessor and a broker. Furthermore, a service to operate the software products is offered. These different products and services are bundled into a cloud service offering, and there usually is a revenue stream compensating for the cloud service offering. There is a strong relationship between the three dimensions and the canvas areas of business models. The relationship between products/services and revenue streams refers to the fact that single products/services or bundles are compensated by the customer. This compensation can be financial (revenue streams) or non-financial (exchange of products, services or information). Thus, for each product there always is a compensation, which in many cases is a revenue stream. Companies maximize their value in this way, Fig.1

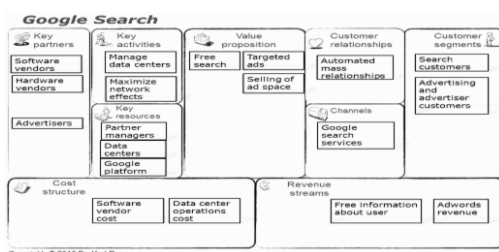


Figure 1: Google's Business Model

Bearing in mind the distinctive characteristics of software products we can conclude that the flexibility of software in combination with human services reveals the wide space for creative business model innovation, in particular in connection with the internet and mobile services.

3. The specifics of high tech product marketing strategy

Marketing strategy is a part of business strategy of the company. That is why it is necessary to pay attention on its specifics in high-tech industries. Excluding the strong technical content, short life cycle and its innovative aspects, a high-tech product should be considered as a product that can satisfy the customers' needs either an individual consumer or an organization. The "high-technology" dimension comes only as an extra layer that is added to a product. It still can be defined by its tangible or service aspect and the nature of its consumer or industrial market. Thus the marketing of high-tech products is no more than a subset of marketing consumer goods; of industrial marketing; or of services marketing, whichever the case may be. It is contingent on the technological context [3,9].

According to some authors marketing managers agree with these findings and claims that, their objectives are not very different from those of their colleagues who work with more products that are traditional. As a common feature between high-tech and other industries can be specified the fact that both types of managers seek to increase their market share and profits while optimizing their available resources according to the product range, the price, the promotion, and the distribution. Even if the basics of marketing concept aren't change, their composition and respective importance will have to take into account the distinctive characteristics of high-tech products. From marketing strategy stand-point there are several specifics, derived from specifics of high-tech products, that should be mentioned. When managers developing marketing strategy they have to take into account the four distinctive characteristics of high-tech products, namely, a tendency to worry many customers, the need for efficient time management, the direct cooperation with the research and development department, and the ever-changing conditions of the markets.

The first distinctive characteristic is predominantly related to the concerns of the customers that they can't managed with the new technology. This is due to different reasons. For example customers are intimidated by the task of learning how to use a high-tech product, some are risk-averse to any novelty, and others are afraid that the current technology available will become obsolete quickly. Consequently, this lead to postpone their buying decisions.

The same pattern of consumer's attitude toward the high-tech products can be found in the organization's managers behavior. Many of them are worried to adopt the new technology and innovative solutions and that's way tend to use various strategies to reduce risks in purchasing high-technology products. They constantly try to evaluate strictly the risk/return ratio of such investments. However, the role of marketing is to make consumers, either final consumers or companies, to be acquainted with innovation, to make them more comfortable with technology and to help them to work out precisely the return on their investment.

The second distinctive characteristic, namely the short product life cycle, requires efficient time management including development of schedules and defining marketing time limits. From time period perspective the average life cycle of a personal computer, a mobile phone, and many consumer electronics, is under one year while the number of models is increased dramatically. The high-tech industry is similar to fashion industry, since more than 90 percent of the models change every 6 months. [6]. Therefore, operational excellence and agility becomes of a prime priority, not only in development and manufacturing, but also in marketing. In other word if they miss a sale a drop of 30% in margins of the producer's sale price will occurred. As an example can be shown Apple. In 1990s they underestimated demand for two of its best-selling products and in turn it had lost around \$300 million in potential sales. Furthermore, the market for these products had disappeared. The positive effect was that Apple learned the lesson and today it can now make and deliver a

computer ordered on-line within 3 days. The same marketing pattern concerns industrial products which also have a short-term life cycle. In application software, the life-cycle duration is at most 2 years. Similarly, in the firewall market, a new product can become obsolete within 12 months, and that makes time to market critical problem for any firewall vendor, like Cisco Systems, Nokia, IBM.

Product innovation, as a third distinctive characteristic, requires interactions between research and development and other services. According to findings of numerous studies, conducted by academics and practitioners research and development and marketing interact and have a significant role in the new product development process. Their main conclusion is that the integration of research and development and marketing can cause influence on the success or failure of new product development projects, both at the project and the company [4]. From managers perspective this close collaboration is not limited to the development of new products. It is also very important in all the different stages of product management, starting with the product launch and ending with its exit from the market, as well as in the management of the different components of operational marketing. Some scholars and practitioners believe that the most important driver of a high-tech firm's performance is the interaction between marketing and research and development capabilities [6].

The last one, related to the ever changing conditions of the market is of vital importance. This is due to the fact that sometimes technology will dramatically change the market conditions by creating an exceptional attraction for a product. For example, consider broadband technology. Consulting firm McKinsey estimates that more than 40 million households and businesses had subscribed to broadband, and more than 100 million people around the world had access to it. This means that broad band has achieved around 25% penetration only for six years from its launch. According to the literature in US in 1925, only one in 10 households had a radio, but by 1930 more than 45% of households were tuning in. In 1950 fewer than 10% of U.S. households had a TV, but after 5 years that number soared to 65%. The most important characteristics of high-tech products marketing is that that it crosses the boundaries of B2B and B2C.

There is a general perception that the marketing of technology is essentially important for market organizations. But there is no denying that technology is penetrating the consumer markets very rapidly, due to the adoption of information technologies, such as the personal computer, the cellular phone, and the Internet. This is also can be noticed in the new developed strategies of the largest high-tech firms. Companies such as HP, IBM, Microsoft, and Nokia are marketing solutions for both business customers and consumers. Some B2B companies seceded in entering the consumer market very successfully. From one hand can be pointed out HP with its digital cameras and Samsung, which is today the second leading producer of cell phone handset. On the other hand Microsoft and Dell Computer have made substantial penetration into the professional markets.

4. Conclusion

Taking into consideration mentioned above we can conclude that product marketing and product management are deeply connected. Despite the fact that product management deals with control over the product, its development, and lifecycle, while product marketing is focused on bringing a product to the customers, both processes have shared stages and deliverables and

above all they start at the same point - a product vision. That's why it is very important to understand the distinguishing characteristics of the products, since it appears that traditional marketing and management concepts and tools should be adapted to the specific requirements imposed by high-tech products. With so much unpredictable change, which are typical for those kind of industry, managers experience difficulties to predict which practices, firms, industries, and geographies will dominate two or three decades from now. But, if they have a deep knowledge of the nature of their products they will be able to apply principles that can stand the tests of time and help managers overcome both internal and external challenges to their business.

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THE INFLUENCE 2% ADHESION PROMOTER ON COEFFICIENT OF FRICTION OF OPP, PE AND PET FILMS HAS BEEN ADDED INTO FLEXOGRAPHIC INKS

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1. Introduction

For a numbers of years, flexo printing has been one of the most important processes for the printing and other products in the high quality required. Today printing technology is highly automated in all phases of processing. Production times have shortened, while the quality of the final product has been improved steadily [10],[5].

Working in virtually every facet of our lives, friction is the unseen force that allows, or hinders the movement of two surfaces that are in contact with one another.

A packaging film's "coefficient of friction" (COF) provides a relative indication of frictional characteristics. Coefficient of Friction, COF, is a very important parameter in the process of flexographic printing. For film substrates are particularly important to determine the static and dynamic coefficient of friction. Controlling COF gives processors the ability to optimize performance and avoid problems in forming, transporting, and storing of packages. Research has therefore been undertaken to determine the effect of the adhesion promoter on the coefficient of friction for OPP, PE, PET films.

2. Objective and research methodologies

The test of COF were made for OPP, PET, PE films, which is a printing substrate:

- before printing, substrate OPP, PET, PE,
- immediately after printing,
- after 20 minutes and after drying at 50° C.

The printing sample were made using Labratester-automatic machine.

The sample has been dried in a laboratory oven, SML.

The coefficient of friction, COF, was measured by using a Zwick / Roell.

The adhesion promoter reference No. 70GH278345 does not contain acetylacetone.

It is used in flexo printing in order to improve adhesion and temperature resistance in following Gecko based series: Gecko Frontal Eco, GFE, Gecko Frontal Uni, GFU, Gecko Frontal Shrink, GFS, Gecko Bond Top, GBT, Gecko Bond Star, GBS.

The research has been focused on dynamic Coefficient of Friction for printing substrate, OPP, PET, PE film and Gecko Frontal Eco CMYK printing inks, surface printing.

2.1 The equipments



2.1.1. The machine Zwick / Roell testing machine equipped with appropriate fixturing to determine the coefficients of friction. The equipment used to measure the COF of the film.



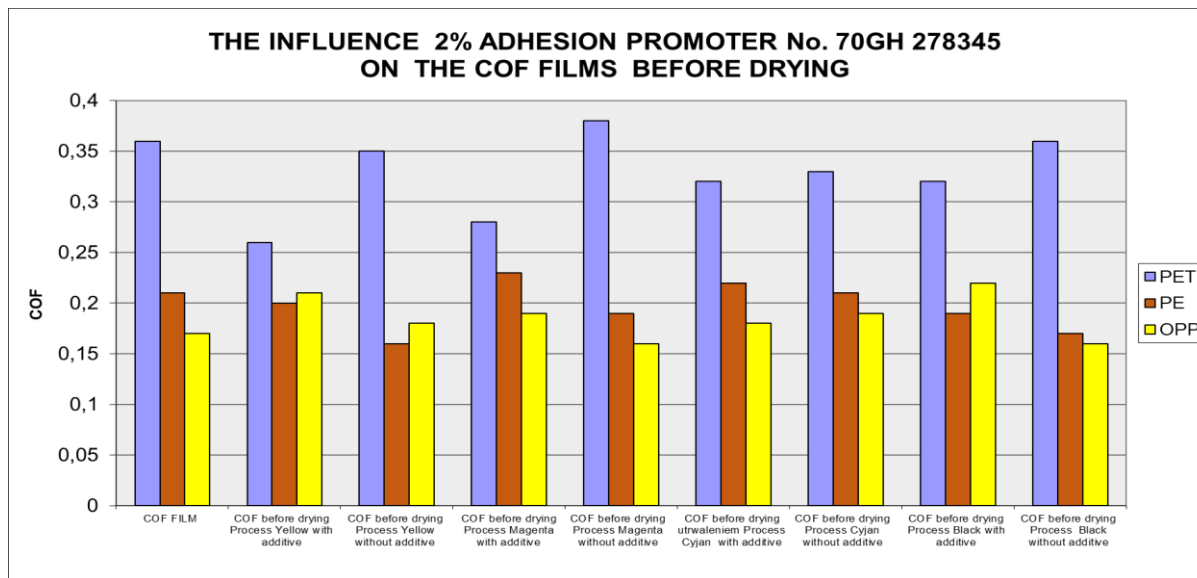
2.1.2. The laboratory oven SML



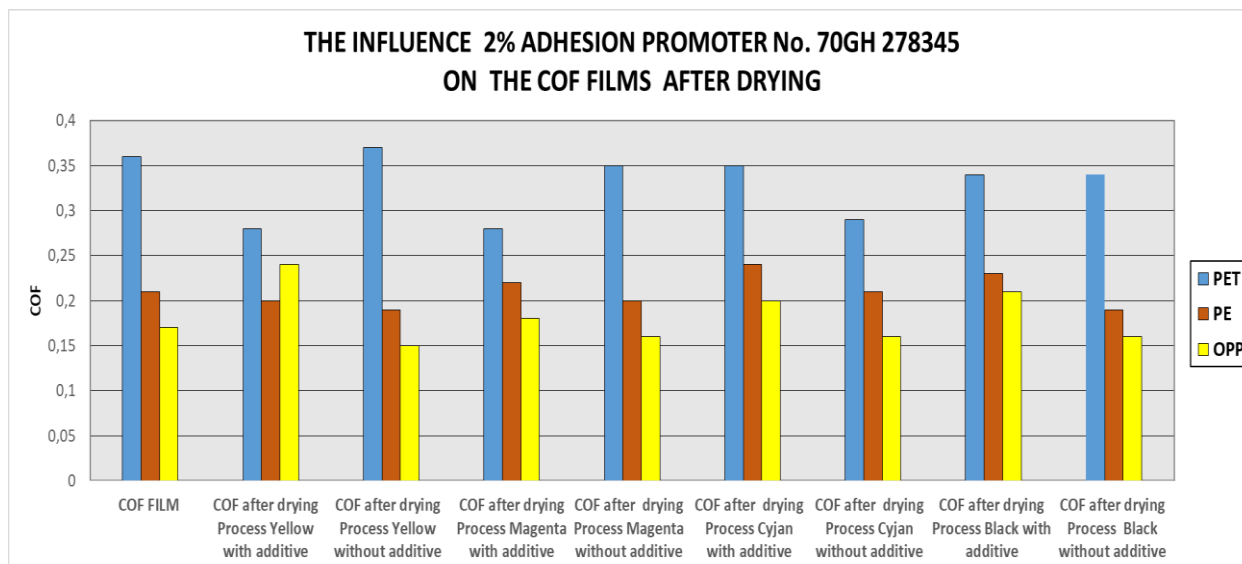
2.1.3. Labratestr automatic machine

2.2. The results

2.2. 1. The result of influence 2% COF on films before drying



2.2.2. The result of influence 2% COF on films after drying



3. Conclusion

This study provides information about influence ready ink and additive on COF films.

The influence on COF film has ready ink without additive. In the most cases the printed ink reduces the COF film. The 2% additive added into ink a little bit increase the COF films.

It changed even after drying and depended on what inks and what substrate was tested.

The additive added in the ready ink has a different effect on the coefficient of friction, depending on:

- the quantity of the additive,
- the type of film,
- the type of ink,
- drying time the printed samples.

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REEFER CONTAINER POWER SUPPLY AND SUPERVISION SYSTEM ONBOARD RAILWAY WAGONS

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Abstract: Concerns about greenhouse gas emissions and environment protection in general, lead to application of new, eco-friendly solutions in almost all areas of human activities. Today, transportation is in the focus of many researchers since transport units generate substantial emissions locally as well as globally. Turning to electricity powered transportation units seems to be a logical step if global power production transitions to renewable energy sources (large hydro, wind, solar, biomass, etc). This paper demonstrates a technical solution applicable to reefer containers railway transport, as an alternative to road transport with conventional trucks or railway transport with diesel gen-sets. In fact, reefer containers are frequently used to transport sensitive goods. Therefore, containers must be almost constantly supplied with electric power to maintain desired ambient parameters (temperature, humidity, number of air changes per hour, etc.). An innovative technical solution which provides suitable power supply to reefer containers aboard wagons has been developed and tested in real-life conditions. Electrical power is drawn from the locomotive's single-phase, head-end-power line (usually 1500 Vac, 1500 Vdc or 3000 Vdc), available at the locomotive, or on wagons with electric installation. Throughout the paper, the developed static converter system suitable for transforming single-phase 1500 Vac, into three-phase 400 Vac, 50 Hz is presented. Furthermore, a dedicated communication system is developed which enables users to perform supervision of transported goods (temperature and relative humidity) and track the reefer container onboard railway wagons.

Keywords: REEFER CONTAINER, STATIC CONVERTER, RAILWAY TRANSPORT, REMOTE SUPERVISION

1. Introduction

Intermodal (multimodal) transport of refrigerated goods demands continuous, stable power supply in order to preserve the quality of products inside reefer containers, transported from origin to destination. Modern refrigerated containers are such that they allow maintaining goods' temperature in the range of -25 to +25 °C. This in turn permits to transport virtually any goods requiring special temperature conditions. Reefer containers, while on ship, get power supply from ship's low voltage electric distribution system. When disembarked at port, reefer containers are powered from the land power distribution system. Land power connection provides reaching desired transport temperature, therefore permitting the containers to travel a limited period of time without power connection. At arrival terminal the container is reconnected to the power supply and hopefully the temperature inside the container hasn't raised above permitted level. If longer transport time is required, reefer containers must be powered. Naturally, for higher ambient temperatures and/or prolonged exposition to direct sunlight shortens allowed unpowered transport period, Fig. 1.

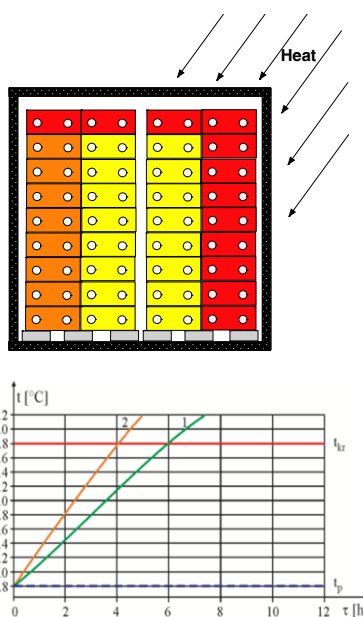


Fig. 1. Up - schematic diagram of arrangement of carton boxes filled with bananas in the reefer container; bottom - cargo's (banana's) temperature rate of rise in the upper layer of carton boxes (marked red in left figure) inside reefer container cut-off from electricity supply source, [1]

At present, railway transport of refrigerated containers with a connection to a power source is not common within EU railway system. On the other hand, a number of legal EU railway norms does not allow usage of any autonomous units to supply several containers with electricity at the same time. Despite the fact that there are self-contained diesel generator units, manufactured with dimensions of ISO-containers, for safety reasons, they are not allowed for use on EU railways.

The use of non-autonomous generators, serviced and maintained by service personnel, is not less difficult. Firstly, the extremely high labour cost in the EU makes such an approach inapt. Secondly, such transport requires specialized carriages both equipped with diesel generators, and passenger spaces to carry the servicing staff.

Another way of refrigerated containers railway transport in Europe is transport using gensets. In fact, these stand-alone diesel generators are a universal tool that is commonly used on vehicles as well as on the railway. Generator's capacity and fuel tank allow the units to supply one container with electric energy for a few days.

However, this solution is often compromised in the case of fuel theft, genset theft, fuel leakage, fuel lack, gen-set failure, etc. resulting in power loss and damage to transported goods.

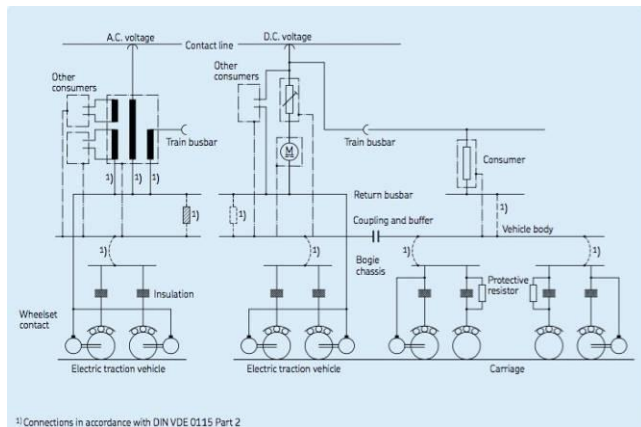
If power supply is removed, independent on its cause, a serious extraordinary situation arises. In fact, when electric power supply is cut-off from the reefer container, the compressors of the cooling system stop as well as the fans which provide temperature uniformity of transported goods. Therefore, the temperature field inside the container becomes very non-uniform, especially in the case of cargo temperature rise. Container heating from above by direct sunlight makes natural convection of the air through the gaps between stocks of carton boxes placed on pallets difficult, Fig. 1. As a result, the outer layers of carton boxes full of cargo (e.g. bananas), marked red and orange, have a higher temperature than those placed in the middle, and the calculated delay of heating the inner carton boxes as compared with the outer boxes amounts from 4 h to 8 h, [1].

Having in mind afore stated shortcomings of reefer containers railway transport relying on diesel generators, a research and development project has been conducted that resulted with a static power converter for railway application that mitigates highlighted problems.

2. Reefer container wagon power supply system

At the Faculty of Engineering in Rijeka, Croatia, in cooperation with the company Transagent also from Rijeka, supported by the European Union from the European regional development fund a research and development project has been conducted that resulted with a reefer container power supply for railway wagons. The developed power supply fulfilled all basic requirements for reliable reefer container railway transport in controlled conditions without “fuel dependence”. Electric power for the reefer container power supply is drawn from the train’s single-phase, head-end-power line (usually 1500 Vac, 1500 Vdc or 3000 Vdc), available at the locomotive, or on wagons with electric installation, connected to the locomotive. The constructed power supply includes a step-down, single-phase power transformer, an AC/DC rectifier, DC link, a DC/AC inverter and an output filter. Due to considerable permitted deviations from the nominal voltage, according to the relevant (e.g. UIC 552, IEC 60850, etc.) railway standards, a carefully designed control of the static converter system had to be developed.

Electric energy distribution from the locomotive’s main power transformer to the last wagon in the railway composition is performed with a single power line i.e. a high-voltage railway cable of appropriate cross-section. The cable runs through a non-magnetic metallic conduit which protects the cable from mechanical stress. The conduit of appropriate diameter is fixed to the metallic construction of the wagon, [2]. The return conductor of the high voltage head-end-power circuit are the rails, composed of the wheelset contact assemblies with brushes (1 grounding circuit per axis), and protective resistors (1 resistor per axis), Fig. 2. The wagon’s earthing system is designed as to comply with the standard



DIN VDE 0123.

Fig. 2. Wagon's grounding system, [2]

Electrical interconnections of wagon's electric power system are performed with appropriate standardized elements, in compliance with the railway standard UIC 552, Figure 3.

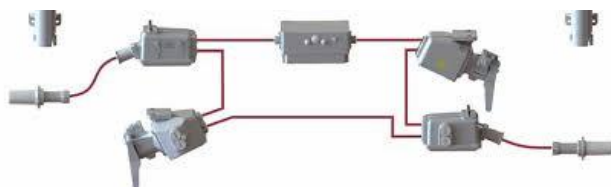


Fig. 3. Connection elements according UIC 552, [3]

The main component of the reefer wagon power system is the power converter that provides stabilized, sinusoidal, 3-phase output voltage 400 V, 50 Hz. As previously mentioned, the power converter consists of a 1-phase, step-down transformer, AC/DC rectifier, DC link capacitors, DC/AC inverter and a smoothing output LC filter. The reefer container wagon power supply is based on high power insulated-gate bipolar transistor (IGBT) switching technology. Before constructing the full-scale power converter, a

prototype converter of same topology but with reduced power was constructed and tested in laboratory environment, Fig 3.



Fig. 3. Small scale prototype model of the power converter

The desired characteristics that the full-scale power converter for railway application should possess are listed in the following table.

Table 1: Desired parameters of the power converter for railway application

Power [kVA]	>18,75
Input voltage range [V]	1000-2000, 1ph
Frequency of input voltage [Hz]	50
Output voltage [V]	400, 3ph
Frequency of output voltage [Hz]	50
Output voltage waveform	sinus
Converter rated power [kVA]	> 20
Temperature range [°C]	-30 to +40
Max. dimensions [mm x mm x mm]	2000x1500x600
Standard compliance	UIC, IEC and RIC

The following two figures demonstrate the influence of the smoothing output filter ($C=100\ \mu\text{F}$, $L=200\ \mu\text{H}$) upon the voltage waveform.

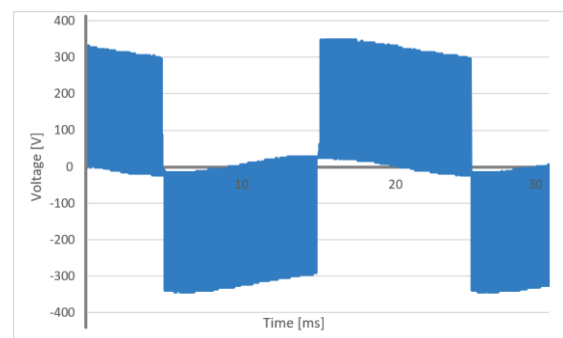


Fig. 4. Voltage measured in front the smoothing filter of the power converter

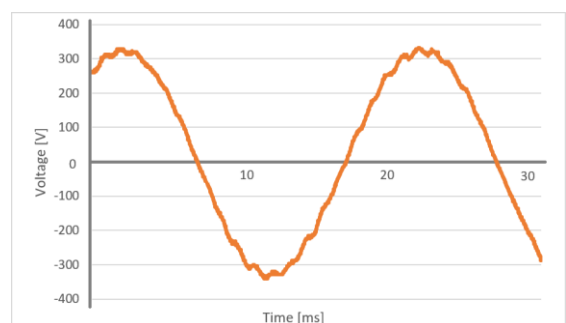


Fig. 5. Voltage measured at smoothing filter terminals of the power converter

Figure 6. demonstrates voltage waveform dynamics upon start-up and shut-down of the power converter.

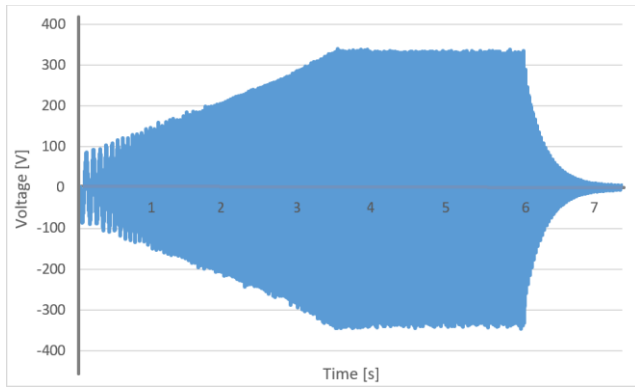


Fig. 6. Voltage transient at power converter terminals upon start-up and shut-down

After extensive testing in laboratory conditions on the small-scale prototype model, a full-scale model (Fig. 7) was constructed with constructive parameters as defined in Table 1.



Fig. 7. Full-scale power converter during vibration testing

The nominal power of the converter was selected to be 30 kVA in order to withstand the starting current of older generation reefer containers, [4].

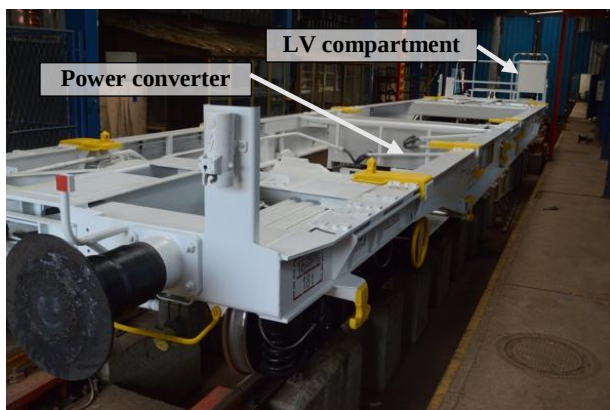


Fig. 8. Wagon after installation of the reefer container power supply system components

Furthermore, the converter had to be equipped with an appropriate switch-disconnector for isolating the converter from the input high voltage (1500 Vac) and grounding for safe operation on the converter and to comply with stringent railway norms. Also, the converter is equipped with a device for emergency start/stop in all conditions. The power converter itself is in a metal housing of appropriate size with adequate cooling openings providing IP67 protection degree. The metal housing is therefore attached to the metal construction of the wagon, as visible in the following figure.

Distribution of low voltage power (400 V, 50 Hz) from the power converter to the industrial sockets designated for power

supply of the reefer containers is performed with low-voltage railway cables of appropriate cross-section and number of conductors. The cable is run through a metallic conduit of appropriate diameter, which protects the cable from mechanical stress and is made of non-magnetic material. The conduit is fixed to the metal construction of the wagon. The industrial sockets are of the 3p+PE, 32A, 400V type, IP67 protection degree and located in a metal housing with lockable door.

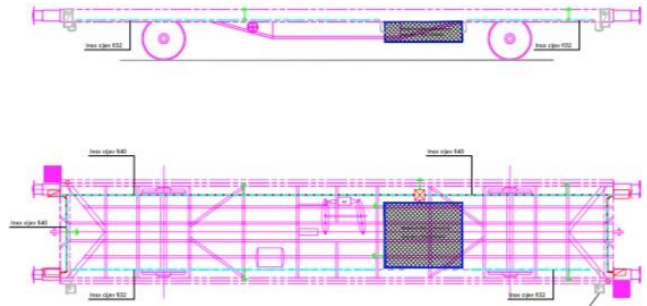


Fig. 8. Reefer container wagon with power supply - layout

3. Reefer container remote supervision system

Tracking transport of goods in reefer containers along the supply chain is the means by which product quality can be guaranteed, [5]. Integration of emerging information technologies can now provide real-time status updates. In fact, in order to ensure real-time monitoring of reefer container's power supply, a dedicated communication system has been developed using industrial grade communication equipment (GSM/GPRS modem). The application running on the GSM/GPRS modem has been developed and coded in LUA programming language.

Reefer container's remote supervision system consist of several key elements:

- GSM/GPRS modem running the developed application for remote supervision for both the power converter and the reefer container powered from the converter,
- Server application that collects data from the GSM/GPRS modems,
- Mobile application for remote supervision of reefer containers installed on user's mobile phone.

Remote communication with the power converters installed on railway wagons and with reefer containers powered from these converters is done by Orbcomm's IDP 782 module for cellular fleet management, Fig. 9.



Fig. 9. IDP 782 – GSM/GPRS module for remote communication, [6]

The software application running on the IDP 782 module was written in LUA programming language and provides serial communication on Modbus protocol. Since there are two serial ports on the IDP module, one is used for communication with the

power converter operating software while the other is selected for communication with the reefer container's control system.

Extensive testing by the principle of "trial and error" has been undertaken in order to establish communication with reefer container's logic i.e. microcontroller, Fig 10.



Fig. 10. Reefer container used for communication testing purposes

At the same time, a server application has been developed that collects data from the IDP 782 module. The data transmitted to the server application includes reefer container's parameters (container ID, temperatures, humidity, alarms, ...) power converter data (status, power, energy, alarms, ...) and actual GPS position.

Finally, a mobile application has been developed that permits registered users to remotely supervise reefer containers powered from developed converters during railway transport. The mobile application shows the user actual GPS position of the reefer container, ambient parameters inside the container and electric parameters reflecting power converter's operation, Fig 11.

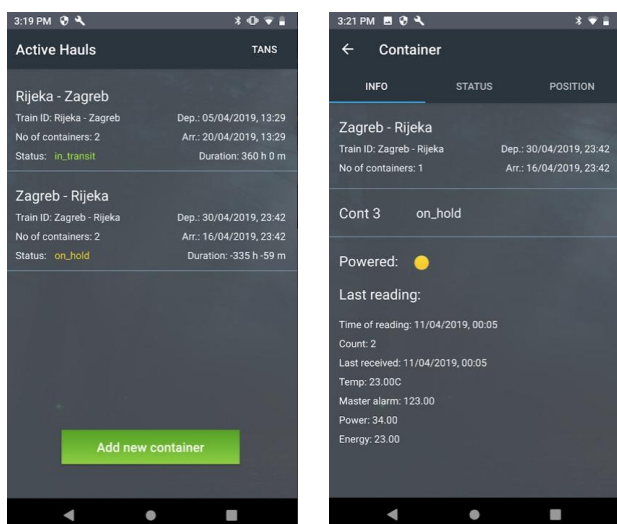


Fig. 11. Mobile application for reefer container remote supervision

4. Conclusion

Railway transport of refrigerated containers with a connection to a reliable power source is not common within the EU railway system. Today, it is common to power up containers at the

departure terminal, thus ensuring desired transport temperature, and afterwards permitting the containers to travel for a limited period of time without power supply. In order to overcome the necessity for limited travel time and/or short travel distances a technical solution was developed that is based on power electronics technology. In fact, a high-power converter for railway application was developed. The power converter is powered from the train's head-end-power line (usually 1500 Vac, 1500 Vdc or 3000 Vdc), available at the locomotive, or on wagons with electric installation. The developed converter is resilient in terms of substantial input voltage fluctuations permitted by the railway regulations, due to large capacitance of converter's DC link.

A dedicated communication system has been developed using industrial grade communication equipment that permits the users to remotely supervise reefer containers while on railway wagons. The communication system consists of a GSM/GPRS modem running an application that continuously communicates both with the power converter logic and with reefer container logic circuits. The serial communication is based on the Modbus industrial protocol. Apart from the software application running on the GSM/GPRS modem, a server application has been developed that collects data from the modem. The data transmitted to the server application includes reefer container's parameters (container ID, temperatures, humidity, alarms, ...) power converter data (status, power, energy, alarms, ...) and actual GPS position. Also, a mobile application has been developed that allows registered users to access server data containing information regarding their reefer containers while on railway wagons during transport.

Future research and development will be focused on a multi-voltage power converter that will provide full compatibility with all railway standard voltage ratings. In fact, a multi-voltage power converter is already undergoing testing procedures.

5. Acknowledgment and disclaimer

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The authors share full responsibility for the contents of the manuscript.



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CONDITIONS FOR APPLYING OF TOOLS FOR THE FINISHING PROCESSING OF HOLES THROUGH SURFACE PLASTIC DEFORMATION

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Abstract: The schemes of tools for Surface Plastic Deformation (SPD) in processing holes is the most spread method in the processing engineering. Rotation rolls (balls, cone-shape or spherical rolls) are being used as deforming elements. They deform through axial feeding, rolling over the processed surface. There are two main groups of tools – “Tools operating with axial feeding” and “Tools with radial feeding”. The main feature of the tools with axial feeding is the helical character of the trajectory of the deforming elements on the processed surface. These tools have some disadvantages which could be avoided by using the tools with radial feeding, the tools with periodical radial feeding and the tools with dynamic work.

Key words: surface plastic deformation (SPD), axial feeding, radial and periodical radial feeding, dynamic work.

1. INTRODUCTION

Surface Plastic Deformation (SPD) is a heavy-duty method for finishing processing of details. It provides a combination of geometrical and physical characteristics of the quality of the working surfaces, which has a great impact on their exploitative properties [4, 5, 10]. There are plenty of other advantages, which motivate the wider spread of SPD, and also the necessity of its improvement and appropriate applying. In most of these cases, the deforming elements are rotating bodies applying their deformation effect, rolling on the machined surface [2, 5]. Deforming elements are also used which are a guide-smoothing elements with prismatic shape operating at a sliding friction on the machined surface [1, 7].

Combined tools combining the cutting and SPD are also being used at machining of internal cylindrical surfaces [3]. The cutting can be performed either by boring [10] or by tools for deep drilling [8].

Depending on the properties of the contact determining the scheme of kinetic interaction between the technology system elements, there are two kinds of tools [4, 5, 6, 10, 11].

2. ANALYSIS

Tools operating by schemes corresponding to those for processing through cutting, are known as “Tools operating by axial feeding” (Fig.1, a). This group has been used since the earliest stages of application. It helped the creation of a great number of constructive variants of tools, operating by forces axial feeding or by feeding themselves [11]. A basic characteristic of the tools by axial feeding is the helical character of the trajectory of the deforming elements on the processed surface. It takes a guaranteed recovering of the generant, which length is equal to the length of the contact zone. The reason for that is the short length of the deforming elements (balls, cone-shape or spherical rolls). It is known that pressure doesn't divide equally in the zone [4]. Its maximum value and the ones near it, determining the primary effect of the deforming impact, include a section long around one third of the length of the generant. This means that at 50% recovering of the generants, there will be sections of the surface with varying degrees of deformation alternate with each other on the processed surface. This results in different values of the quality parameters. The reducing of this nonhomogeneity requires working with low feeding but it usually is economically unprofitable. In practice we usually use several times greater feeding. However, the increase of the feeding goes together with an increase in the nonhomogeneity of the quality of the processed surface. The increase of the number of the deforming elements reduces the negative consequences of this disadvantage but it

cannot remove it completely – the greater number of the deforming elements makes the instrumental equipment more expensive and puts limitations related to the diameter of the processed holes. There are some defects characteristic to the tools with axial feeding [10]:

- limited application for short holes with high requirements for accuracy, resulting from a too high increase of the share of the so called “extreme effect” (an increase of the diameter of the hole in close proximity to the breaks of its surface);
- these tools cannot be used for processing of holes which have unlocked contour and diameter less than 25mm in length
- these tools have limited possibilities for correcting of the accuracy of the form of the holes because of the short length of contact of the deforming elements and the processed surface;
- the productiveness is limited by the possibilities for increasing of the axial feeding.

In the other group – “Tools without axial feeding” – most of the indicated defects are overcome. Their basic characteristic feature is that the length of the contact zone between the deforming rollers and the surface of the hole is equal to the length of the generant of the processed cylindrical surface. This is a precondition for realization of heavy-duty finishing processing. The group of the tools without axial feeding includes the tools with radial feeding, with periodical radial feeding and with dynamic work [4].

The tools with radial feeding (Fig.1, b) use long conical rolls as deforming elements. Their characteristic features are: their productivity is considerably higher than the tools with axial feeding; the time for processing doesn't depend on the hole length; the extreme effect is inconsiderable; the kinematics of the process is simpler (there is not axial feeding of the rolls); there is the possibility of processing with high accuracy and processing of interrupted surfaces [6].

The negative aspects of these tools are caused by the conical form of the deforming rolls [10]. The conditions at which the deforming effect on the processed surface is going are unequal, this caused by the difference of the diameters in the separate radial sections of the rolls sliding along the whole length of the contact zone and the change of its width. The gradient of the change of these conditions is as higher, as greater is the angle of the cone of the deforming rolls. The indicated unequal conditions determine not-homogeneity in the quality along the length of the processed surfaces.

The deforming elements of the tools with periodical radial feeding (Fig.1, c) are cylindrical rolls [3, 10]. The use of such rolls leads to elimination of the defects related to the not-homogeneity in the quality of the processed surfaces. There are other characteristic features of the tools with periodical radial feeding, namely:

- there isn't relation between the diameter and the length of the processed holes – this makes them applicable in wide field of diameters (from 10 to 200mm);
- they have simple, reliable and technological construction, which allows them to be used for various metal cutting machines (universal-, special-, automatic-, multi-purpose and other machines).

The tools with dynamic work (Fig.1, d) have cylindrical deforming rolls. Their main feature is the short period of the contact action between the rolls and the processing surface. This results in effects that allow processing of details for which the use of other kinds of SPD tools is not possible because of the little stability of the walls of the details.

The particular constructive variant provides coordinated rotary motion of two concentric separators, in which there have been placed respectively percussive and deforming rolls. The separators rotate at different angular speeds, therefore:

- they create preconditions for control of the process of forming of the secondary longitudinal ruggedness. That gives the desired parameters of the quality of the processed surfaces;
- by means of regulation of the frequency of rotation of the separator of the percussion rolls it is possible to create effects typical for the tools with elastic work.

The indicated characteristics of the varieties of holes processing tools and of the processes realized through them lead us to make the following considerations related to their field of application:

- the processing of interrupted cylindrical surfaces requires the use of tools at which no axial feeding motion is realized;
- it is expedient to use tools with axial feeding with the length of the holes greater than 260 mm, if the loss of bearing area of the connection must not be higher than 5%;
- the use of tools with radial and periodic radial feeding with of the processed holes over 160mm is approved;
- the possibilities for application of the tools radial feeding are narrow because they depend on the proportion between the length and the diameter of the holes;
- the tools with dynamic work overcome the difficulty in processing thin-walled and unequal-walled details which makes them a successful replacement of the tools with radial and periodic radial feeding;
- the use of the tools with periodic radial feeding and those with dynamic work allows us to achieve much higher homogeneity of the quality of the processed surface, compared to the tools with radial feeding;
- the possibility to control the tools with dynamic work, thus securing equal deforming force, and the possibility the tools with radial feeding to operate as ones with elastic work, allows us to reach homogeneity of the roughness within a pack of details;
- the possibility to regulate the size of the diameter of the tools with axial and radial feeding (within certain limits) allows them to be used for processing of holes with small differences in their nominal diameters;
- if it is possible to use two or more than two kinds of tools, the choice depends on the economic evaluation.

On the basis of the explained considerations it has created and algorithm for the choice of an instrument for SPD. Beside the four shown schemes of tools it is produced a fifth one, related to the use of guide-smoothing elements with prismatic shape (Fig.1, e) [9]. They can be applied for machining of holes with different diameters.

3. CONCLUSIONS

1. The described properties of the tools with and without axial feeding show that they are sufficiently varying and cover a great range of technical requirements of the processed surfaces. This is a precondition for expanding of the application of the SPD method.
2. The differentiation of these properties requires a strict defining of the fields of independent application of a particular scheme of instrument with an emphasis on the actuality of application of the tools without axial feeding.
3. The created algorithm (Fig.2) for choice of an instrument for SPD is a precondition for the introducing of automated projecting

of the technological equipment which is used for realization of the SPD method for processing of holes.

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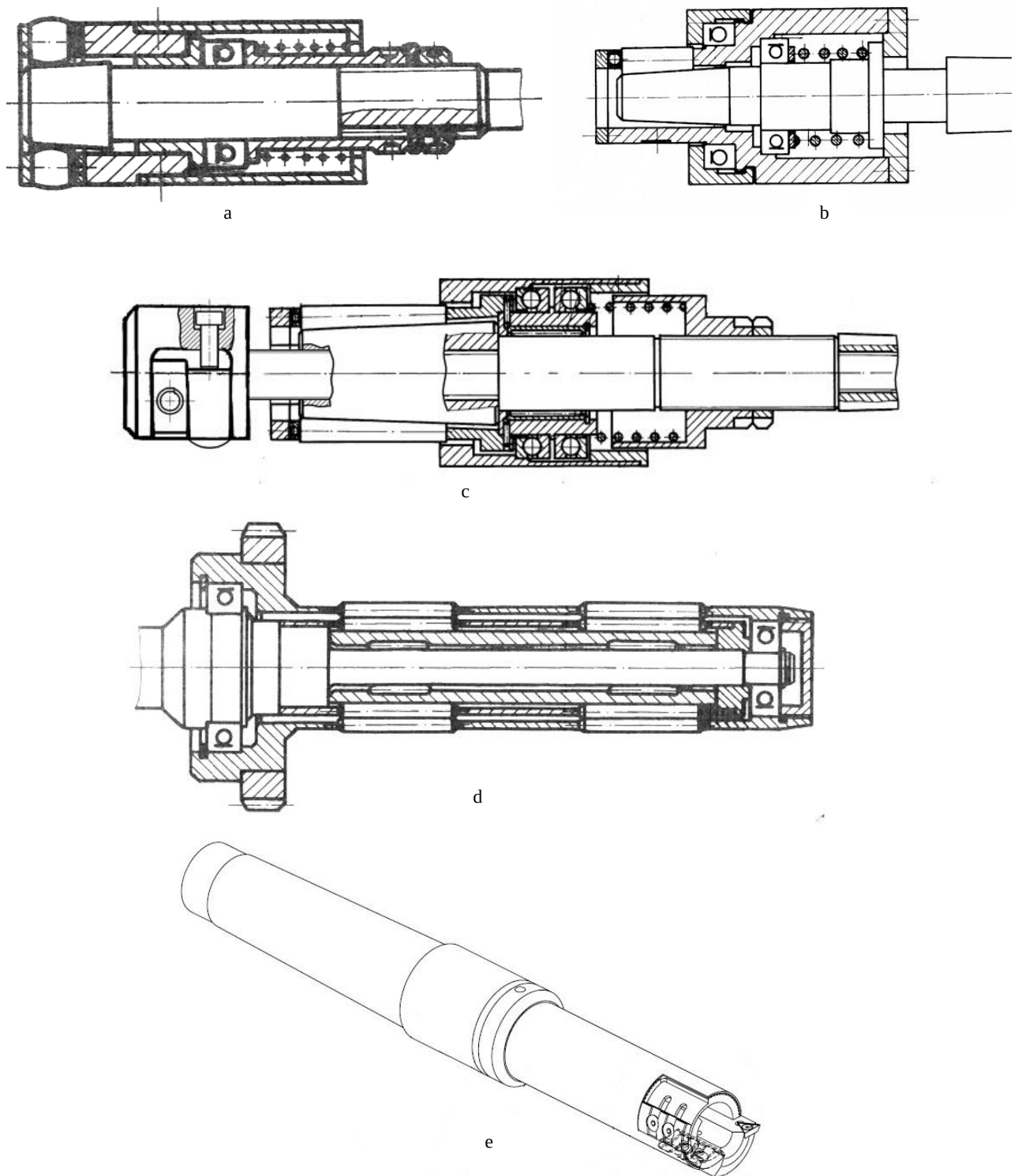


Fig.1 *a* - Tools operating by axial feeding; *b* - Tools with radial feeding; *c* - Tools with periodical radial feeding; *d* - Tools with dynamic work; *e* – Combined tool for hole making

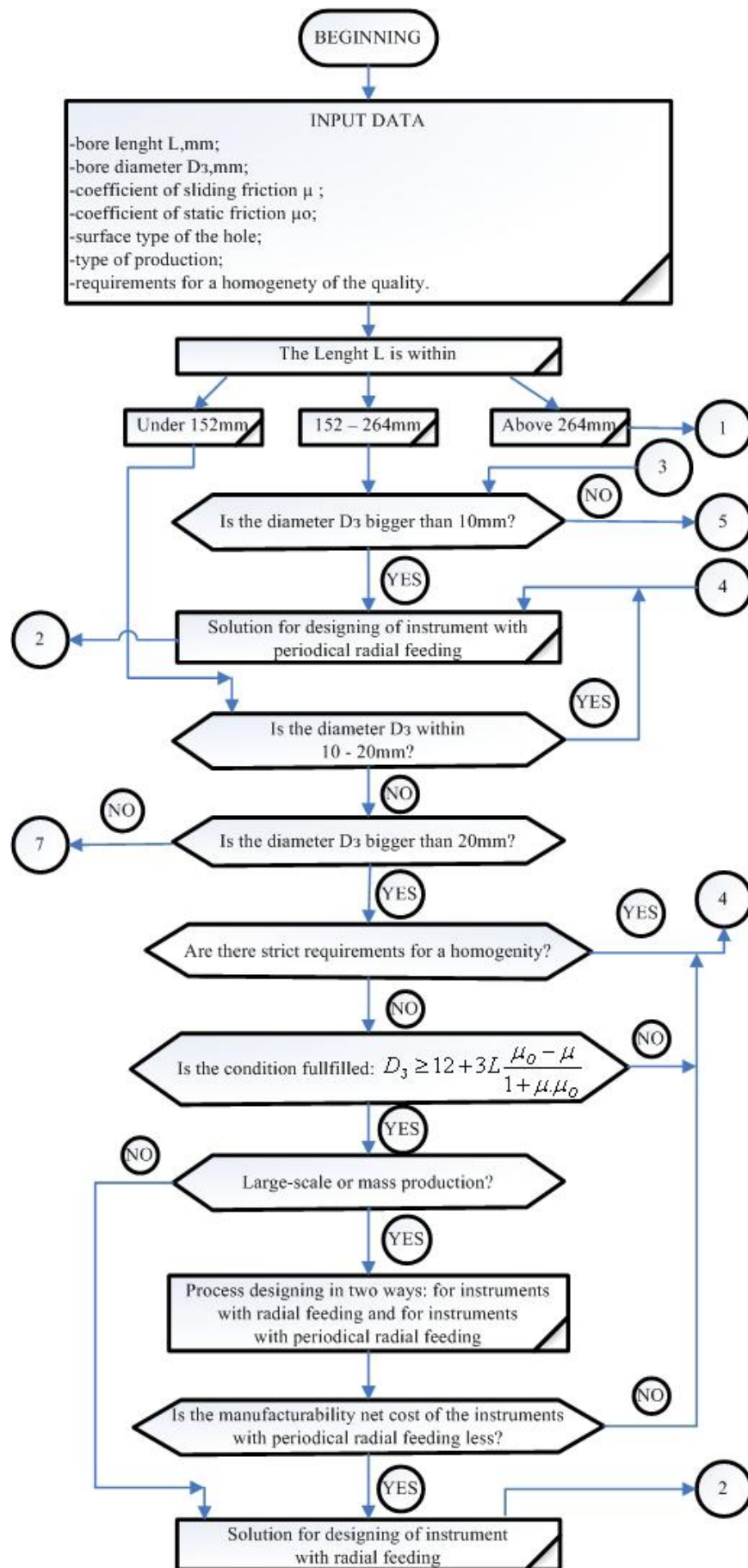


Fig.2 Algorithm for choice of an tool for SPD

Continuation of Fig.2

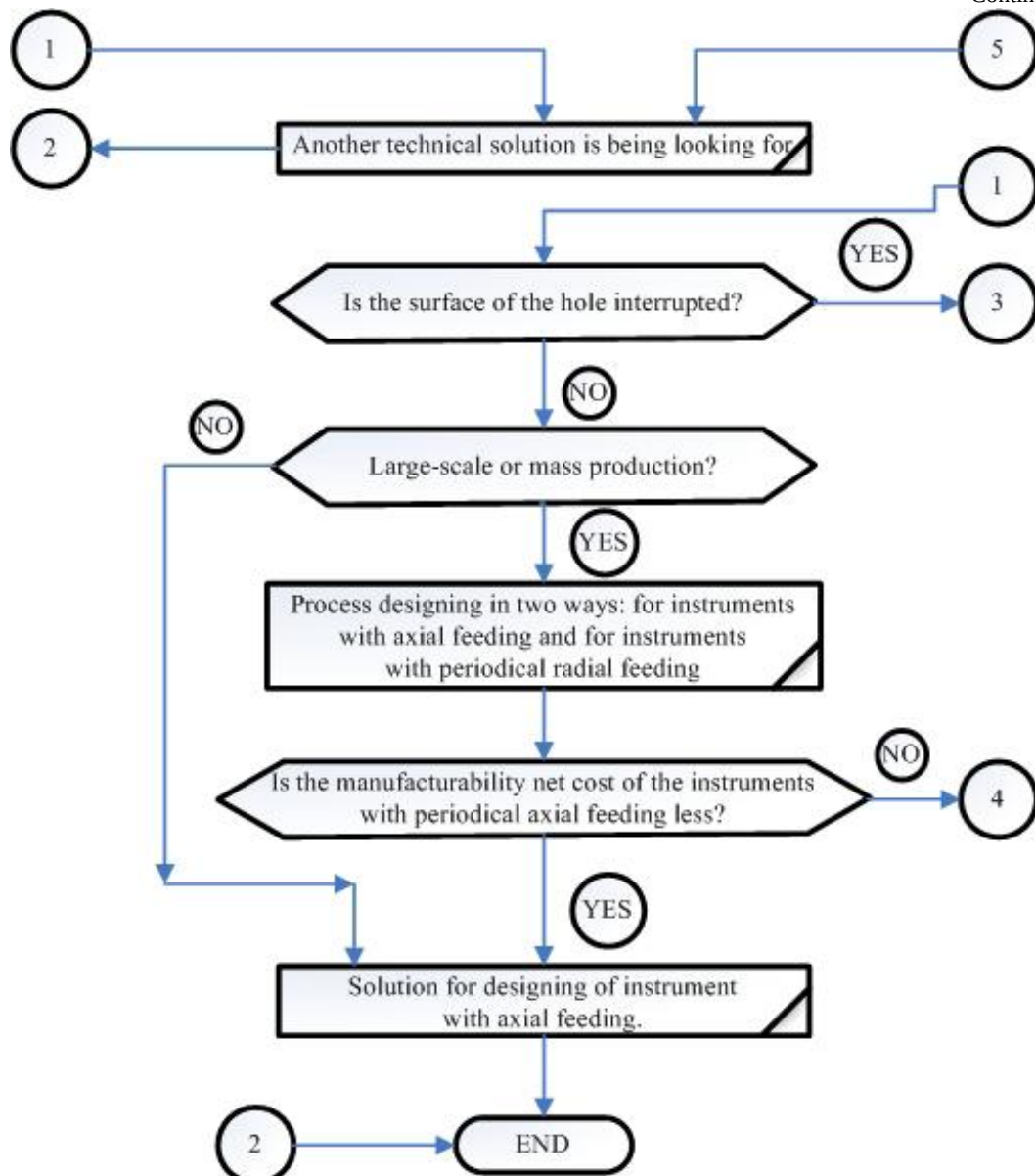


Fig.2 Algorithm for choice of an tool for SPD

DESIGN OF AN INNOVATIVE LUGGAGE STORAGE SYSTEM FOR PASSENGER TRAINS

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Abstract: Due to the small and strictly organized space of a train car, the internal dimensions offer limited possibilities to redesign and extend the luggage storage space in order to accommodate a larger baggage. In order to have easy access and to be user friendly, the aim of this paper is to design an external baggage storage system for passenger trains. The system proposed, has a chain transmission and it is designed to accommodate the biggest size luggage commercially available.

Keywords: LUGGAGE STORAGE, TRANSPORT SERVICE, DESIGN

1. Introduction

Railway passenger transport ensures the movement of passengers and their luggage, with a higher degree of safety. It is done day and night and is carried out in a predefined schedule system. This study is focused on an innovative luggage storage system which can be a new direction for the railway industry, applicable to other means of public transport. A solution to rethink the luggage storage inside the wagon is presented in this paper. The possibility of relocating the space storage outside of the wagon, refers to the development of a modular design. This can solve the deficiencies of storage spaces without affecting the operation of the train and without making important structural changes to the wagons.

An analysis has been done based on passenger-baggage relationship on how to use the luggage storage space. Depending of the nature of the goods transported by passengers, the design of the wagon and the storage space has its limits.

2. Innovative luggage storage system description

The basic problems faced by the passenger while carrying a luggage inside and outside the train are the following [1]: low or non-existent storage space (number and size of luggages, placing luggage under the seat) (figure 1a); climbing and descending on stairs with hand luggage [2]; difficulty to perform basic movements inside the wagon with the luggage in the hand due to width aisle of only 60 cm (figure 1b)[3]; the lack of an adequate security system; the presence of many pieces of luggage in the interior reduces movement (figure 1b); damage of luggages due to inappropriate transport (figure 2a) and to inappropriately handled (figure 2 b).

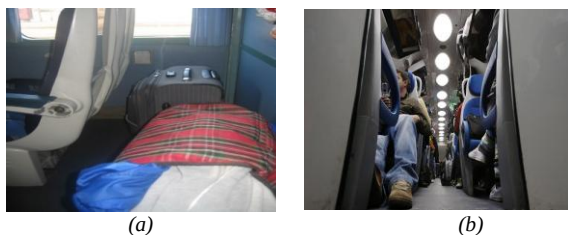


Fig. 1 a) the aisle from passenger wagon; b) inappropriate storage space for luggage

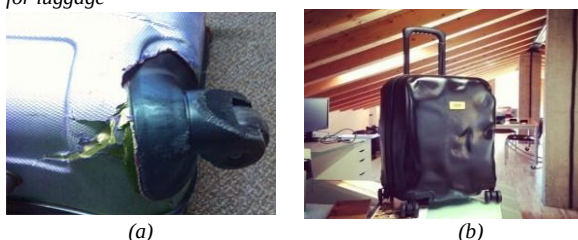


Fig. 2 a) damaged wheel; b) damaged plastic luggage

Rail infrastructure is regulated by rigid safety requirements and European standards. Due to this fact, this paper proposes two solutions for extended luggage storage without altering the wagon configuration. The first solution is a module that can be attached to the wagon (Figure 3a). The second one, is placing the module in another wagon especially designed only for luggage (figure 3b).

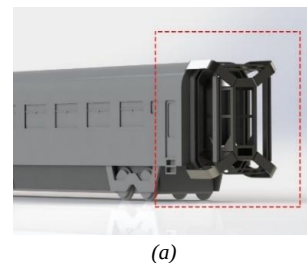


Fig. 3 a) modulus that can be attached; b) wagon especially designed only for luggage

In order to devise a new storage system an algorithm was developed to take into account all variables (figure 4).

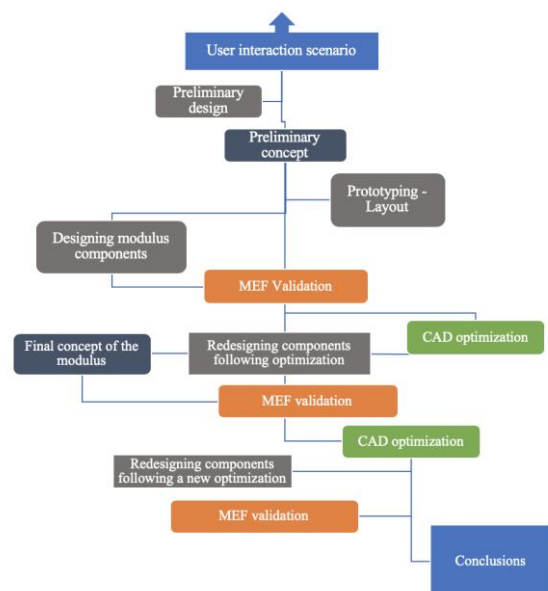


Fig. 4 Algorithm for designing a new luggage storage system

The analysis of the interior of the wagons and the general configuration of the train leads to an optimal solution to place the storage system modulus outside of the wagon. Thus, it becomes a component that can be adaptable to different types of wagons.

The positioning of the storage system modulus outside the train was designed in compliance with the standards of the maximum permissible gauge on the railway tracks (figure 5) [4]. Also elements of morphology and functionality, passenger interaction

solutions were taken into account, resulting in a proposal that complies with the safety requirements imposed by the standardized passenger carriage system. The proposed solution is a fixed, modular structure that can be attached to the ends of the train wagons, making a common body with the wagon. The development of such storage space is only allowed on the longitudinal axis of the train. The positioning of the modulus can be seen in figure 6.

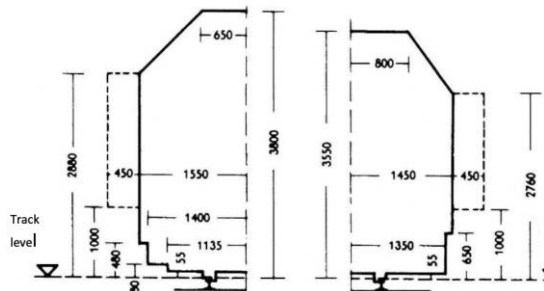


Fig. 5 Standards dimensions for train wagons

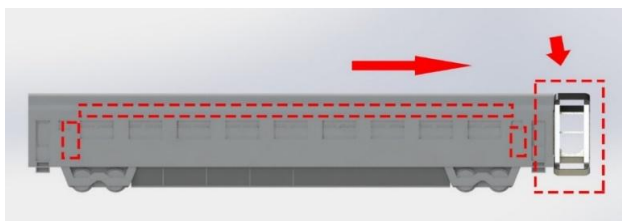


Fig. 6 Position of the storage luggage system

The storage modulus is composed of a metal structure frame and capsules where the luggage can be placed (figures 7). In figure 8 b can be seen how the metal frame of the modulus is positioned on the wagon. This type of structure permits the existence of a passage lane through the storage modulus, allowing the movement between wagons (figure 8a).

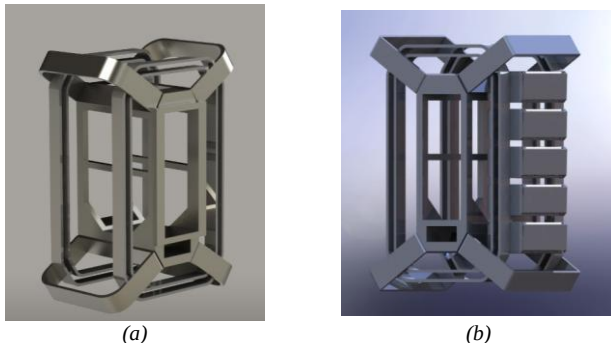


Fig. 7 a) metal structure frame; b) metal structure frame with storage capsules

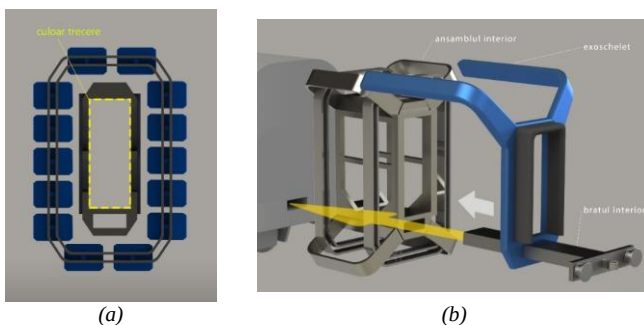


Fig. 8. a) Passage lane through the luggage storage module; b) Module coupling system, common to the wagon

This type of system involves low costs, having already all the information in order to ensure its compliance with the UIC regulations. The installation of the luggage storage system wagon is the same as that of a standard wagon. The internal metallic structure consists of metal beams, inside of which there is a set of 14 capsules mounted on a conveyor system, able to pick up and deliver the luggage under different height conditions imposed by the parking station architecture (train position according to platform) (figure 7 b). The morphology of this structure allows the allocation of a passage space between wagons, while also allowing access to the inner capsules. At the bottom, below the passageway, there is a channel that traverses the whole structure, making it possible to fix the module through a clamping arm using the original coupling architecture of the train (figure 8 b).

The module will not take over the loads resulting from the train movement. The coupling is independent, without dispersion of the forces, resulted from the dynamics of the train in its structure.

The 14-capsule assembly is driven mechanically by an electric conveyor system capable of taking over and delivering the luggage by repositioning the capsules on a required route. Each capsule has the dimensions of 119cmx50cmx72 cm = length x height x width, achieving an optimum volume that can receive the largest luggage at this time in the market (figure 9).

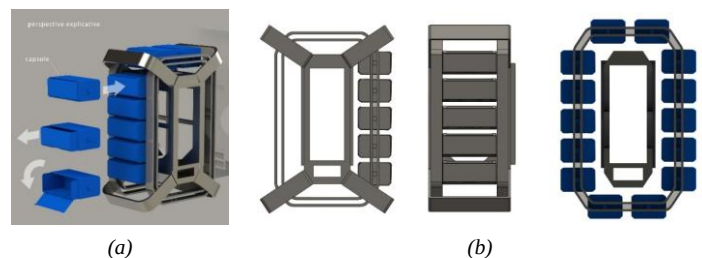


Fig. 9 a) Detail of storage capsules; b) Storage mode capsules views

The closing and opening system of the storage capsule provides user access on both sides, depending on the position of the train to the platform and consists of three elements: the frame that provides the clamping of the module transport system, a drawer that can slide 50% on the outside, on both sides and the door which in the open position forms a ramp to be able to place the luggage more easily into the capsule.

3. Optimisation of the luggage storage system

The capsule system is developed in parallel with the structure of the module influencing each other in terms of morphology and functioning mechanics.

This has led to dimensioning the module around the capsule gauge. For the construction of such a product, a material with special properties is required which can withstand stress, vibration, wear due to the loading and unloading of other products of different density, weight and roughness, temperature changes depending on the season, maintenance and the level of complexity for manufacturing [5]. As a material, polycarbonate meets the requirements so is the optimal choice due to its unique properties [6].

The shape of the storage capsule results from the standard baggage dimensions and the need for a required space, circulation inside the module and end-user relationship. Due to the standard market size of luggage, influenced by railways' rules, the capsule had to adopt the highest standard size for accommodating all types of luggage. The functional model of the capsule was determined by the analysis of the movement space inside the module and the need to be accessed on both sides by the user. The material chosen for the construction of this capsule is also polycarbonate with outstanding strength, low weight, ease of manufacture and maintenance and low wear due to repeated luggage storage [7].

The outer shell protects the capsules and the entire inner mechanism from the outside (figure 10 b). On this cover are mounted vertical sliding doors (figure 10 b) when the train is stationary. Thus permitting access to the capsules and barcode scanner which will forward the information to the requested capsule

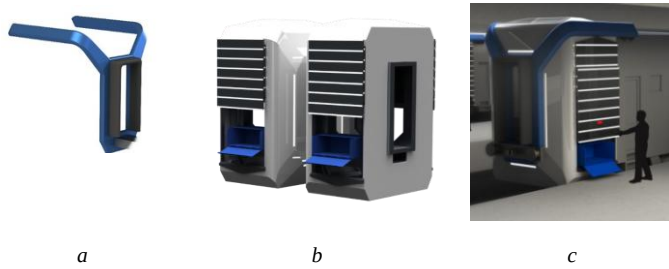


Fig. 10. a) clamping system for the outer shell; b) Outer shell for the modulus; c) final design of the modulus.

The clamping system used to fix the outer shell does not involve major structural changes for the wagons, retaining the same type of standard coupling and a simple solution for mounting the module (Figure 10 a)

Thus, the module represents an attachment that can be dismantled if there is no need to use it, without the wagon requiring modifications to be put back into operation as a result of the module removal.

4. Conclusions

The design concept is a viable solution that aims to solve, even partially, the issues raised based on user-baggage relationship on how to use the luggage storage space.

The new storage system, in the given context, provides adequate space for storage, easy access and independent use without auxiliary staff.

The proposed system brings added comfort to passenger rail transportation. The luggage storage system fluidizes passenger traffic by allowing them to climb and descend more easily. The proposed module offers a high level of safety for passengers due to the innovative luggage storage system.

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THE RESEARCH PECULIARITIES OF PARAMETERS AND CHOICE OF AGRICULTURAL MACHINES IN PEDAGOGICAL TECHNOLOGIES FOR INNOVATIVE PROJECT ACTIVITY IN TRAINING AGROENGINEERS

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Summary. *The structural-logical model of training of future specialists in agroengineering for innovative project activity has been developed on the basis of a systematic comprehensive study of the theoretical course of agricultural machines, the deepening of the students' scientific work on the development of supporting and moving elements of machine-tractor units, including pneumatic tires. The samples of individual fragments from the algorithm and the method of calculation of wheels used in the educational process are provided and the general and professional competencies of the agroengineer are created, especially during the implementation of future specialists in agro-industrial production of higher education courses in the course of master's and master's studies. It is noted that the training of agroengineers for innovative project activities is carried out in accordance with the Law of Ukraine "On Higher Education" and the standards of higher education of Ukraine. The influence of interdisciplinarity in the system of cross-cutting project preparation on the readiness for implementation of production practical tasks is investigated. It is confirmed that the support-run elements of aggregates in the conditions of complex terrain contributes to the development of erosion processes and negatively affect the soil fertility. Any tire better satisfies the condition of permissible wheel pressure on the soil if the air pressure in the tire is low. Improving the technological process of manufacturing tires for agricultural purposes allows them to ensure their quality, reliability and operational safety.*

KEYWORDS: WHEEL TIRES, AGRICULTURAL MACHINERY, TECHNOLOGY, PROJECT TRAINING, PROJECT ACTIVITY, STUDYING PROCESS, THEORY

Introduction.

Science and education are closely interconnected and able to develop effectively in a single integrated system of scientific, methodological and pedagogical activities. Educational process is an intellectual, creative activity of scientific and pedagogical workers, students, practitioners and other interested subjects in the sphere of higher education and science [1].

The training of future agroengineers is based on the formation of professional competences in a harmoniously developed personality capable of solving various tasks of production activity. The object of the study and activities of the agroengineer are the phenomena and processes associated with the effective functioning of agricultural machinery and mechanized technologies in agro-industrial production [2]. The educational process of students of the specialty "Agroengineering" is aimed at training specialists capable of solving professional specialized tasks and applied problems related to the use of agricultural machinery in mechanized production technologies, primary processing, storage and transportation of agricultural products, technical service of mechanization facilities, etc.

In the structural and logical scheme of training future agroengineers, the basic discipline is "Agricultural machines", students learn about the structure and principle of operation of agricultural machines, regulation and adjustment of them for optimal modes of work, as well as the theoretical basis of technological processes of working bodies, the method of development and designing new and improving existing structures [3]. Studying discipline in addition to classroom activities involves the independent performance of course work, the purpose of which is the technological development of the design of agricultural machinery or its units, or the improvement of existing machines to ensure the implementation of mechanized production processes of growing crops and improving the operational, economic and environmental performance.

The main scientific directions of the master's work in the field of agroengineering are to increase the productivity of aggregates, expand their versatility, combine energy resources with other implements and ensure their reliable handling, minimize the negative impact on the environment and soil, improve the working conditions of machinery, as well as traffic safety. Agricultural machine-tractor aggregates are driven across the field by overwhelming majority by means of a wheeled driving system. The processes that occur when the wheels interact with the soil, affect not only the performance of the machines, but also the properties of

the soil, as the object of cultivation and the environment of cultivating crops.

Practical, scientific and educational activities show that the problem issues on the peculiarities of the substantiation of parameters and the choice of tires of agricultural machinery wheels in pedagogical technologies of agroengineering training for innovative project activities are still insufficiently studied and require further fundamental theoretical and experimental studies, scientific substantiation and generalizations.

Prerequisites and means for solving the problem.

For a long time, scientists have been engaged mainly in the study of the processes of interaction of the running system with the soil and traction-coupling properties of machines. Regarding the deformation of pneumatic tires of agricultural wheels, these issues are not sufficiently studied.

The problem issues related to the design of agricultural machinery, preparation of agroengineering specialists for the project activity, including the features of substantiation of parameters and selection of tires of wheels, are not sufficiently studied.

In [4], the main components of the preparedness for the project activity of the agroengineer as a specialist are presented, which are united in physical and mathematical, general technical and special blocks and general and professional competences, which should be mastered by the bachelor of specialty 208 "Agroengineering". For example: to design equipment and equipment of production areas, agricultural machines, their knots, mechanisms, various connections; carry out standard design calculations of knots and parts of machines and non-standard equipment; rational assembly of machine aggregates in existing production lines of crop and livestock production; to determine the technical condition of tractors, cars and aggregates of complex equipment [2], to optimize transport processes, etc.

In [5] presented an innovative system of scientific and methodological developments that affect the formation of special professional competencies of agroengineering. The basis of this system is the latest textbooks, manuals, monographs, programs and other teaching materials, as well as advanced pedagogical technology of training, which is based on the progressive, phased development of the future specialist's readiness for the project activity. Such pedagogical technology of training provides a comprehensive, comprehensive formation of professional competencies of agroengineering in accordance with regulatory requirements and standards of education, including [1, 2]. Students'

scientific activity, which is based on the development and modernization of agricultural machinery, plays an important role in the design training. It was noted [5] that the first voluminous work of the student in the educational process is the course work on the discipline "Agricultural Machines". Its successful implementation is a solid ground for effective and effective graduate design, writing master's thesis.

The general issues of the theory of design training were studied deeply by: Bryukhanova N.O. [6], Kolesnikova I.A. [7], Gorchakov-Siberian M.P. [7], Nychalko N.G. [8], Zyazun I.A. [8], Goncharenko S.U. [8] et al. The theory, methodology and practice of design training for agroengineering, including in view of the design of agricultural machinery, were studied and investigated: Bendera I.M. [9, 10, 11], Duganets V.I. [12], Pryshliak V.M. [4, 5, 13] and others. Also, the questions of improving the methodology of preparing future engineers are devoted to the work of A. Asherova, O. Kovalenko, M. Lazareva, D. Chernilevsky, P. Yakovyshina, and the methodological aspects of the future of agroengineering have been reflected in the scientific researches of I. Buzik, A. Demin, S. Daukilas, A. Esaulov, P. Luzan, V. Manke, I. Palamara, S. Pastushenko, V. Yaroshenko, transformation of independent educational activity into readiness for professional self-development by means of technologies of personally oriented education – is reflected in the monograph Bondar M.M., Zhuravsky L.M., Ostapenko E.O., Pryshliak V.M., Kutsenko A.G. [14].

Actual issues of studying the design, operation of tires, reducing the harmful effects of the effect of running systems of the machine tractor unit on the soil are devoted to the work [15, 16, 17, 18], and their production – [18, 19].

Solution of the examined problem.

As noted in [5], the theory and practice of project preparation for future agroengineering involves the widespread use of a scientific component in the educational process during classroom classes, independent work of students. The scientifically substantiated cross-cutting, interdisciplinary, sequential and phased development of agricultural machinery involves achieving a high quality learning outcomes and innovative technology development. Apart from the fact that students during their studies at the institution of higher education take part in research processes, conferences, construct and model the means of mechanization, they are to complete the term paper at the 3rd year, and in the master's degree - a master's degree. Here, students mainly count, design and study the working bodies of agricultural machines. However, there are works in which auxiliary but very important nodes, mechanisms or systems of machines are presented. The same applies to the support and running elements of agricultural machines, including wheel tires.

The type of wheel tires of agricultural machines should be selected, taking into account the permissible action of the wheels on the soil. Preferably the ecological pressure limit of the wheels on the soil, depending on its type and state, is taken at a pressure of 0,1-0,15 MPa.

First, for one of the circuits [3], it is necessary to determine the radial load of the wheels on the soil (kN), which will correspond to the required lifting capacity of the wheels of the machine, using the formulas:

for front wheels

$$G_2 = 10^{-3} a Q_M g / n_2 L; \quad (1)$$

for rear wheels

$$G_1 = (10^{-3} g Q_M - n_2 G_2) / n_1, \quad (2)$$

where a – center of gravity of the car relative to the rear axle, m [3];

Q_M – operating mass of the machine, kg [3];

g – acceleration of force weight, m/s²;

n_2 – number of front wheels [3];

L – longitudinal base of the car, m [3];

n_1 – number of rear wheels [3].

After receiving the radial load of the wheels on the ground, you can proceed with the selection of the necessary tires, following this sequence of actions. First, using the calculated payload capacity of the rear and front wheels (G_1 and G_2), for tabl. 1 choose a tire capable of providing their payload, i.e.

$$G_{uu} \geq G_1, G_{uu} \geq G_2. \quad (3)$$

Table 1

Load ratios and tire pressure to select a mode at 30 km / h.

Tire designation	Air pressure in the tire chamber P_{uu} , MPa								
	0,1	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18
	Permissible load on the bus G_{∂} , kN								
5,0-10		-	-	-	2,1	2,2	2,3	2,35	2,45
6-16		-	-	-	3,4	3,55	3,7	3,8	3,9
6,5-16		-	-	-	3,9	4,05	4,2	4,35	4,5
7,5-20		-	-	-	5,9	6,1	6,3	6,6	6,8
8,25-15		-	-	-	7,95	8,25	8,5	8,8	9,15
9,5-32	6,90	7,30	7,70	8,0	8,4	8,85	9,05	9,4	9,7
9-16	-	-	-	-	8,5	8,85	9,5	9,8	10,45
12-16	-	-	-	-	12,0	12,6	13,0	13,5	14,0
15,5-18	-	-	-	-	13,6	13,9	14,8	15,4	16,4

It has been established that any tire will better satisfy the achievement of permissible wheel pressure on the ground P , if the air pressure in the tire is low. After the previous choice of tires, under its designation in the table. 2 linear sizes are selected: outer diameter D_k and width of the tire ϵ_{uu} . After that, it is checked whether the selected tires are provided to the given ecologically permissible pressure on the soil, using the formula

$$G_{\partial} = 0,12\pi P_{uu} P^2 \epsilon_{uu}^2 D_k^2 / (\pi^2 P_{uu}^2 \sqrt{\epsilon_{uu} D_k^3} + 4 P^2 \sqrt{D_k \epsilon_{uu}^3}), \quad (4)$$

where P_{uu} – tire pressure, MPa (Table 1);

P – permissible wheel pressure on the ground, MPa [3];

ϵ_{uu} – width of the tire (for cars working in intermediate rows, the width of the tire must be less than the width of the row), cm (Table 2);

D_k – external diameter, cm (Table 2) ;

In tabl. 1 shows only data for air pressure in the chamber up to 0,2 MPa. Tires with pressures greater than 0,2 MPa are not recommended for use on field machines

Table 2

Characteristics of tires for agricultural machines

Brief description	Brief description			
	Model	Outer diameter D_k , cm	Tire width ϵ_{uu} , cm	Mass, kg
5,0-10	B-107	51,0	14,0	6,5
6-16	Л-225	75,0	17,5	17,5
6,5-16	Я-275Л	77,8	18,5	25
7,5-20	B-103	91,0	20,5	33
8,25-15	И-83	83,2	22,0	30
9,5-32	B-110	124,0	24,0	50
9-16	Я-324А	89,6	25,5	41
12-16	Л-163	93,0	32,5	44
15,5-18	КФ-105А	98,0	39,5	75

If after the calculations

$$G_{\partial} < G_1, G_{\partial} < G_2, \quad (5)$$

then it is necessary to choose the bus with other parameters; and if the tire could provide a condition

$$G_{\partial} \geq G_{1,2}, \quad (6)$$

it is impossible to pick up, the wheel must be taken with twin tires. In this case, the number of tires for the wheel is determined from the ratio

$$Z = \frac{G_{1,2}}{G_{\partial}}. \quad (7)$$

Then repeat the same calculations for the second scheme of the wheel drive of the car. The numbers for the tire, for example, 5.0-10, reflect: the first figure is the width of the profile of the tire in inches, the second is the tire's diameter on the disc in inches.

As an example, according to such an algorithm, students of the 3rd year of specialty 208 "Agroengineering" conduct substantiation of parameters and choice of tires, performing course work on the discipline "agricultural machines".

During the study in the magistracy, future specialists in agroengineering conduct theoretical and experimental research at a higher scientific level. Let's give an example of conducting such researches for wheels of agricultural machines during their movement in the field.

The processes of interaction of running systems with the soil depend on its mechanical properties, that is, resistance, deformation and destruction. A large amount of experimental data on the patterns of deformation and destruction of soil has been accumulated. But they are of a different nature due to the diversity of soil types, conditions and methods of measurement, and the lack of standardized methods for the integrated assessment of mechanical properties. The use of this data to develop methods for forecasting mechanical properties is not possible. This is due to the large number of proposed empirical formulas and models of deformation of soil [15].

In order to evaluate the interaction of the running system with the soil, the regularity of its compression and displacement is used, which implies the processes of formation of the trace (track) and traction (traction) formation. These patterns are determined by the corresponding displacement of the deformed (dies).

The diagram of the interaction of the rigid wheel with the soil during rolling in a driven mode is shown in Figure 1.

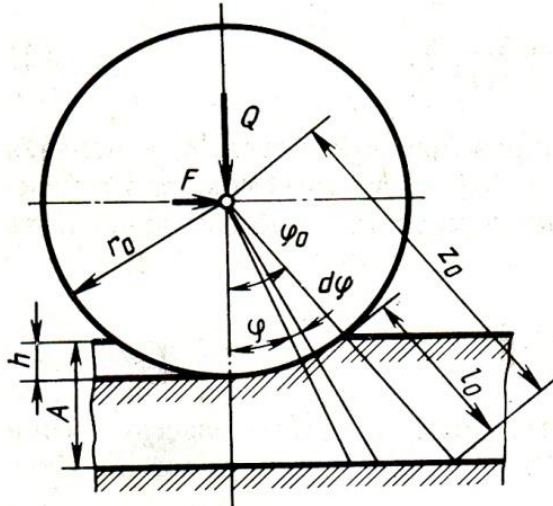


Fig. 1. The scheme of deformation of the soil [15]

Observations show that the deformation of the soil by a moving wheel at different time points extends predominantly to the normal to the rim. Accordingly, the relative deformation ϵ and the rate of deformation $\dot{\epsilon}$, elemental volumes in the sectors corresponding to the corners, $d\phi$ to which all its array is divided into angles ϕ° contact and thickness A of the active layer (deformed) can be represented as follows [15]:

$$\epsilon = \frac{z_0}{l_0} \left(1 - \frac{\cos \phi_0}{\sin \phi} \right); \quad (8)$$

$$\dot{\epsilon} = -\omega \frac{z_0}{l_0} \cos \phi^\circ \left(\frac{\sin \phi}{\cos^2 \phi} \right), \quad (9)$$

where z_0, l_0 – the dimensions are shown in the diagram; ϕ – the value of the contact angle; ω – angle of rotation of the wheel.

Normal wheel load Q and longitudinal strength F , necessary to overcome the rolling resistance, due to the processes of interaction of the wheel with the soil, are equal to the sum of the normal and tangential elementary soil reactions

$$Q = \int_0^{\phi_0} \sigma \cos \phi Br_0 d\phi; F = \int_0^{\phi_0} \sigma \sin \phi Br_0 d\phi,$$

where σ – contact voltage (elementary soil reaction) B and r_0 – contact width and wheel radius.

To solve these equations, it is necessary to use the analytical relationship between voltage and deformation.

The deformation of the soil (its elementary volumes) is completely reflected in the Kelvin model, to which the rheological equation corresponds:

$$\sigma = E_2(\epsilon + \tau \dot{\epsilon}), \quad (10)$$

where E_2 – deformation module; τ – time after action

$$(\text{viscosity ratio } \mu_2 \text{ to the deformation module}) \left(\tau = \frac{\mu_2}{E_2} \right)$$

Pattern of propagation resistance σ_z in depth z in the direction of force P Bussinesca formula is displayed [15]:

$$\sigma_z = KP/z^2, \quad (11)$$

where K – dimensionless multiplier.

To determine the effect of the solid reinforcing layer on the nature of the propagation resistance used correction coefficient.

Also (using coefficients) the Bussinesca formulas are corrected with the aim of approximation of the calculated patterns of propagation of resistance in soft soils to real

Deformation of pneumatic tires and soils adequately reflects the three- and two-element rheological models, respectively. Using the scheme of interaction of the elastic wheel with the soil and the selected rheological models of contacting bodies, we find an analytical description of the processes of simultaneous deformation at wheel rolling. For this, the elementary sector of the scheme of interaction (Fig. 2) will be presented in the form of sequentially placed models of pneumatic tires and soil.

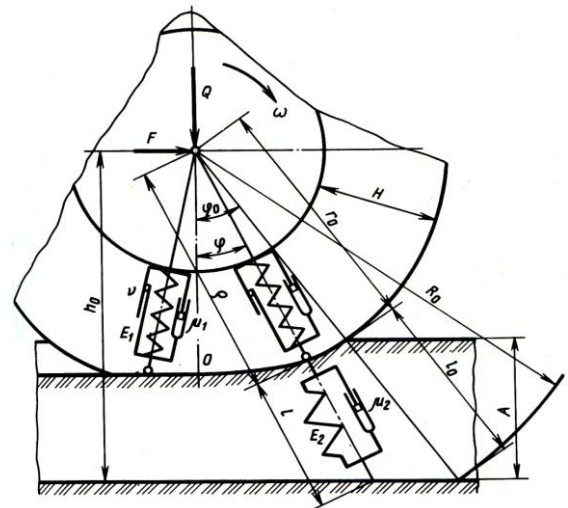


Fig 2. Interaction of rheological models of tires and soil [15].

Determine what changes occur with the models when rolling the wheel on the ground. If time t deduct from the moment when $\phi = \phi_0$, then on the front of the contact $\phi = \phi_0 - \omega t$, – and on the back – $\phi = \omega t - \phi_0 = -(\phi_0 - \omega t)$. Then for any t within the angles of contact, the following relationship is valid [15]:

$$\Delta \rho + \Delta l = \Delta R; \quad (12)$$

$$\frac{d\rho}{dt} + \frac{dl}{dt} = \frac{dR}{dt}; \quad (13)$$

$$\epsilon_1 E_1 \pm \epsilon_1 \mu_1 \pm \nu E_1 \operatorname{sgn} \epsilon_1 = \epsilon_2 E_2 \pm \epsilon_2 \mu_2; \quad (14)$$

$$R_0 \cos \phi_0 = R \cos(\phi_0 - \omega t), \quad (15)$$

where ρ, l, R_0 – the sizes are shown in fig. 2, and $R = \rho + l$. Indices 1 with designations indicate that they belong to the tire, and 2 to the ground. The "plus" signs correspond to the front of the contact, and the "minus" is the rear.

The equation of correlation with respect to deformations and their velocities is obtained after the time division of expressions (12) and (13) into a product $H l_0 R_0$, where H – tire profile height l_0 and R_0 – initial values of sizes R and l .

Can be recorded [15]

$$\epsilon_2 = \frac{\Delta R - \epsilon_1 H}{l_0}; \quad \dot{\epsilon}_2 = \frac{\frac{dR}{dt} - \dot{\epsilon}_1 H}{l_0}. \quad (16)$$

Value ΔR and $\frac{dR}{dt}$ can be found from equation (15), ie

$$\Delta R = R_0 \left(1 - \frac{\cos \varphi_0}{\cos(\varphi_0 - \omega t)} \right);$$

$$\frac{dR}{dt} = -\omega R_0 \cos \varphi_0 \frac{\sin(\varphi_0 - \omega t)}{\cos^2(\varphi_0 - \omega t)}.$$

After substitution, expression (14) values ϵ_2 and $\dot{\epsilon}_2$, represented by the calculation of formulas for ΔR and $\frac{dR}{dt}$, we obtain the differential equation of the interaction of the elastic wheel with the ground

$$\pm \dot{\epsilon}_1 \left(\mu_1 + \frac{H}{l_0} \mu_2 \right) + \epsilon_1 \left(E_1 + \frac{H}{l_0} E_2 \right) = \frac{R_0}{l_0} E_2 \pm \nu E_1 \operatorname{sgn} \epsilon_1 - \frac{R_0}{l_0} E_2 \cos \varphi_0 \frac{1}{\cos(\varphi_0 - \omega t)} \pm \frac{R_0}{l_0} \mu_2 \omega \cos \varphi_0 \frac{\sin(\varphi_0 - \omega t)}{\cos^2(\varphi_0 - \omega t)}. \quad (17)$$

This equation does not have an exact solution, since integrals are not expressed through elementary functions. Numerous methods of integration and grounds for using Taylor series are used for it. These methods do not allow (the second because it is large) to add elementary soil reactions to represent the forces acting on the wheel in the analytical form.

After conducting such an example of theoretical studies, graduates begin to create a laboratory installation and conduct experimental research in laboratory or field conditions.

As a result of scientific research, a pedagogical system was developed, basing on the example of the interaction of the supporting and moving elements of machine-tractor units with soil and on the consistent study of topical production issues, contributes to the improvement of the quality of training and the development of design competencies of the agroengineer.

Results and discussion. The developed innovative system of scientific and methodological training of future specialists is based on a planned, cross-cutting, step-by-step growth of knowledge, skills and abilities of future agroengineering. Course designing and master's work provide a qualitative growth in the design competencies of the graduate.

Conclusion. The obtained results of the conducted research give grounds to conclude that an effective process of formation of readiness for the project activity of future specialists in agroengineering is possible on the basis of cross-cutting innovative teaching technologies. Coursework and master's work contribute to the development of scientific activities. It is important that they have practical orientation, since this will substantially motivate the students to complete them.

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EXPERIMENTAL STUDY ON ENERGY CONSUMPTION IN THE PLASTICIZING UNIT OF THE INJECTION MOLDING MACHINE

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Abstract: Injection moulding is a widespread method of polymer processing. The annual, global energy consumption for injection moulding is comparable to the annual energy production of different European countries. The most energy-consuming stage of the injection moulding is the plasticization process, which needs the energy mainly for the rotational and reciprocating screw motion as well as the heating of the barrel. Both issues were examined by changing various parameters of the injection moulding process, measuring the process characteristics and calculating the corresponding values of SEC (specific energy consumption). Various thermoplastic polymers were examined. It was found that the optimal conditions from the energy consumption point of view is low value of rotational velocity of the screw. Changes of back pressure do not affect the energy consumption of the plasticizing system of the injection moulding machine. Furthermore, an increase of the SEC value with increasing barrel temperature was shown. It was ca. 15% for the average barrel temperature rise of 20°C.

Keywords: INJECTION MOLDING, PLASTICIZATION, POWER DEMAND, ENERGY CONSUMPTION, SEC

1. Introduction

Energy consumption is one of the most important parameters associated with the analysis of technological processes. Energy efficiency of technological processes is one of the critical issues for the manufacturing industry, mainly due to increasing cost of energy and the impact on the environment. Reducing energy consumption is therefore relevant not only for the economic benefits to producers, but also because of the improving of environmental performance of the products manufacture [1-7]. This can be done only with precise knowledge of the production process and its energy characteristics, as well as knowledge of effect of processing parameters on energy consumption per mass unit (called SEC - specific energy consumption).

Injection molding of plastic is now one of the most widely used manufacturing processes. With this technique, millions of parts of various types and sizes, ranging from electronic and electrical components, toys, packaging, through elements of automobile and pharmaceutical industry, until precise microdetails for technology or medicine are produced. Injection molding process is often preferred by designers because of the possibility of applying different polymeric materials and very short process time, as well as the repeatability and accuracy of obtained products. Although polymer materials are characterized by substantial value of SEC at their production stage [8] (Fig. 1), the energy consumption of manufacturing processes of polymeric materials per unit volume of product are extremely low in comparison with other processes [9]. This issue indicates that polymers are one of the most energy-saving materials, taking into account the full life cycle of the products.

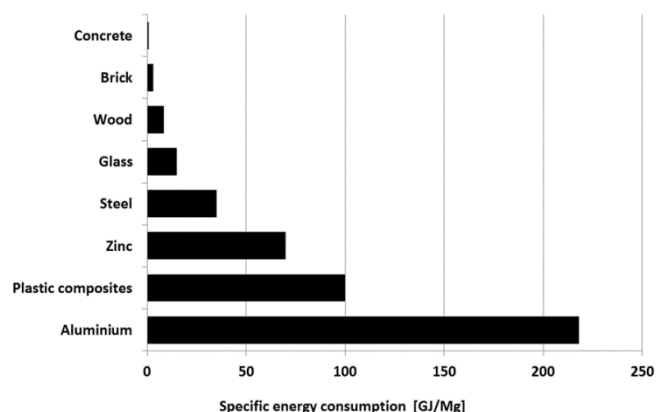


Fig. 1 Approximate amount of energy needed for production of different materials [8]

Because the injection molding process is one of the most energy-efficient manufacturing processes (per unit volume of material), it might seem that it should not require greater attention from the energetic point of view. However, this is the misleading approach, mainly due to the extremely frequent use of injection molding process in the world, and hence the massive amount of polymeric materials processed with this technique. In order to illustrate how large is the consumption of energy in the area of injection processing on a global scale, it is worth to present some literature data [5,9-12]. A life cycle inventory (LCI) of injection molding process indicates that the largest energy expenditure is characterized by the first stage of the cycle - the production of the polymeric material. Figure 2 shows the average values of the LCI for injection molding process of a typical large-scale thermoplastics. The value of the LCI for the polymer production stage is also averaged (PE-LD - 73 MJ/kg, PE-HD - 89 MJ/kg, PP - 83 MJ/kg, PS - 87 MJ/kg) [9].

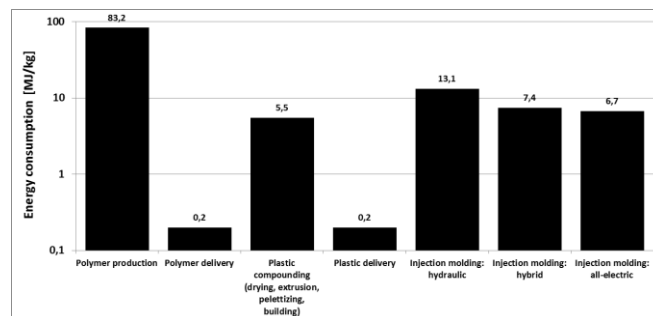


Fig. 2 Energy consumption in the LCI for injection molding [12]

Tab. 1 shows the amount of energy consumed annually in the world by injection molding industry (for LCI, without the polymer production stage – see Fig. 2). In accordance with the recommendations [12] it was assumed that 70% of injection molding machines used in the world industrial production are hydraulic, 15% are hybrid and 15% are full-electric machines. Tab. 2 shows the annual energy production in 2011 in selected countries of the world. In the last few years, energy production in those countries remained substantially constant.

Comparing the data in Tab. 1 and Tab. 2 we can see that the annual energy consumption in injection molding industry around the world is comparable to the order of magnitude with the annual production of energy in different countries. The amount of energy of approximately 10^8 GJ per year is significant on a national scale. Therefore, the problem of energy consumption in injection molding process of polymeric materials seems to be very important. Appropriate control of injection process can result in considerable energy savings while maintaining the suitable properties of the product.

Table 1: Total energy used in injection molding, without material production [12]

Specification	Global [GJ/yr]
4 thermoplastics (PE,PP,PS,PVC)	4.0E+8
all plastics	6.7E+8

Table 2: Annual electricity production in 2011 [13]

country	total electricity net generation [GJ/yr]
U.S.	1,5E+10
Germany	3,0E+09
Italy	1,0E+09
Spain	1,0E+09
Australia	8,6E+08
Turkey	7,9E+08
Ukraine	6,6E+08
Poland	5,5E+08
Sweden	5,3E+08
Norway	4,5E+08
Argentina	4,4E+08
Netherlands	3,8E+08
Czech Republic	2,9E+08
Finland	2,5E+08
Austria	2,2E+08
Romania	2,1E+08
Portugal	1,8E+08

The aim of this work is the analysis of the specific energy consumption (SEC) in injection molding process for five commonly used thermoplastic polymers (PE-LD, PE-HD, PP, PS and POM) at various operating parameters of the injection molding process. The study involved only the plasticizing system of an injection molding machine. It is known that the power demand during the injection molding process is dominated mainly by the plasticizing system, i.e. by a hydraulic motor of the injection molding machine (working during a reciprocating motion of the screw, around 50% of the total power demanded during working of the injection machine) and the heating elements of the barrel (approx. 30% of the total power) [10,11]. More precise analysis of power demand during various stages of injection cycle are presented in [10-12,14]. It follows that a phase of plasticization (rotation and reverse movement of the screw) is the most critical stage of the entire injection cycle from the energy consumption point of view. The effect of the screw rotation stage of injection molding process on the entire average energy consumption is even greater for full-electric injection molding machines than for hydraulic ones [12].

This work concerns study of the impact of most important factors affecting the power demand by the injection molding process. These are power demand by a hydraulic motor (back pressure and rotational speed of the screw) and the heating elements (temperature of the barrel). In the analysis, some less quantifiable factors, such as the energy dissipated in the gear system, have been neglected.

2. Experimental Procedure

In order to estimate the Specific Energy Consumption (SEC) during plasticization phase of the injection molding process, first we have to calculate a power demand by the plasticizing zone of injection machine. Then we can calculate the SEC value as a ratio of the power and the mass rate of plasticization from the formula:

$$SEC = \frac{\bar{P}}{\dot{Q}} \left[\frac{kWh}{kg} \right] \quad (1)$$

where $\bar{P}$ is the average power demanded by plasticizing system [kW] and $\dot{Q}$ is the mass yield of the injection process [kg/h].

Measurement of power demanded by the plasticizing system was made on a research position, consisting of suitably instrumented injection molding machine linked to a collecting and processing data module and a computer for imaging and saving data. An injection molding machine Battenfeld Plus 350/70 was used. The research position was described in more detail in [15]. Five different thermoplastic polymers used in this study are described in Table 3. The product obtained in this study is shown in Fig. 3.

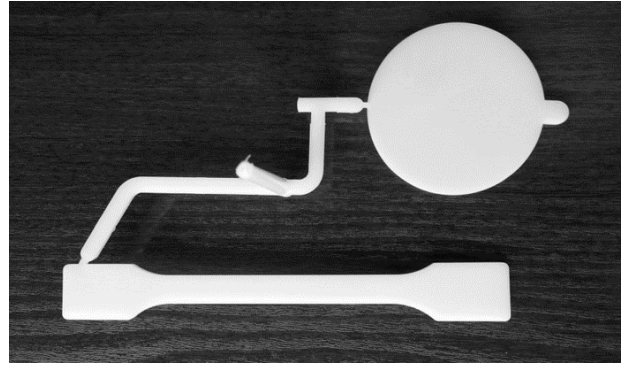


Fig. 3 The element obtained in the study

Table 3: Polymers used in the experiment

polymer	type	MFR [g/10 min]
PE-LD	Malen E FABS 23D022	2,2 (190/2,16)
PE-HD	Hostalen GC 7260	8,0 (190/2,16)
PP	Moplen HP548R	23 (230/2,16)
PS	Krasten 154	10 (200/5)
POM	Schulform 9A	10 (190/2,16)

The average power $\bar{P}$ demanded by the plasticizing system has been related to the time of one whole injection cycle. It was assumed that the total, average power $\bar{P}$ is equal to the ratio of an average energy $\bar{E}_c$ consumed by the plasticizing system during one injection cycle, to an average cycle time $\bar{t}_c$. The energy $\bar{E}_c$ consumed by the plasticizing system during one injection cycle is the sum of an average energy $\bar{E}_h$ consumed by heating elements placed on the barrel at the average cycle time $\bar{t}_c$ ($\bar{E}_h = \bar{P}_h * \bar{t}_c$) and an average energy $\bar{E}_s$ consumed by the injection screw during its rotational movement ($\bar{E}_s = \bar{P}_s * \bar{t}_r$), where $\bar{t}_r$ is an average time of rotation of the screw. So, we can therefore assume:

$$\bar{P} = \frac{\bar{E}_c}{\bar{t}_c} = \frac{\bar{P}_h * \bar{t}_c + \bar{P}_s * \bar{t}_r}{\bar{t}_c} \quad [kW] \quad (2)$$

The power $\bar{P}_h$ demanded by the heating elements was determined by the precise measurement of switch-on time of each heater (all three heaters are powered in discreet way) during the whole time of the experiment. Data of power demand for each heater were collected in 16s-cycles, as it was presented in Fig. 4. Then instantaneous values of power demand P_h for heaters 1-3 were averaged and added together to give the average power demand $\bar{P}_h$.

The average power $\bar{P}_s$ demanded by the screw during the screw rotation time was determined indirectly by measuring the torque (using the device for measurement of torque, mounted directly on a drive system of screw), which was then converted to power by using the known formula:

$$\bar{P}_s = \frac{\bar{M} * v}{9550} \quad [kW] \quad (3)$$

where $\bar{M}$ – an average value of torque on the screw during screw rotational movement [N*m], v – a rotational speed of the screw [rpm].

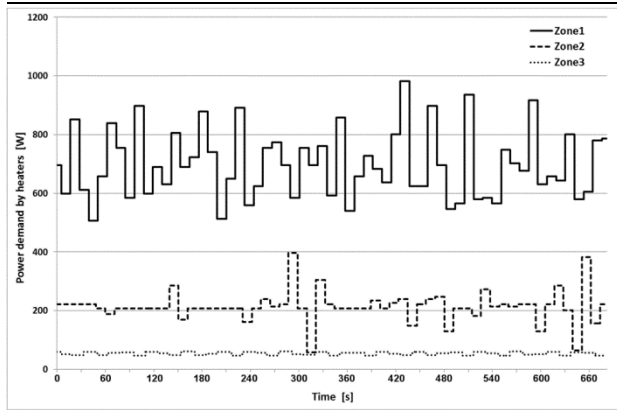


Fig. 4 Sample graph plotting changes of power demand by the barrel heaters during injection molding of PP

The average value of torque $\bar{M}$ was calculated as arithmetic averaging of instantaneous values of measured torque M during the screw rotation movement. Measurements of the torque were performed with a frequency of 50 Hz. The above approach to determining of power demand on the hydraulic motor was made, because other methods (e.g. power demand measurement by assessing the hydraulic pump capacity and its rotational speed or measurement of the power demand by the electric motor, which drives the hydraulic motor) introduce additional errors. In this experiment these errors could be avoided.

The studies of the injection molding process were carried out by varying of selected controllable parameters of the plasticization process in a relative wide range, as shown in Table 4. If one parameter was varied, the other parameters were kept constant, with value equal to the middle (third) of five ones listed in Table 4. For example, for changing the back pressure parameter during the injection process of PP polymer, the other parameters had constant values equal $v_r=240\text{rpm}$, $t_d=20\text{s}$ and $T_b=230^\circ\text{C}$. Others, invariable parameters of the injection process are presented in [15]. No tests for POM at variable barrel temperature were carried out because of a narrow processing window for this polymer [16]. Moreover, tests for PS at variable screw velocity were also not carried out for technical reasons. The viscosity of melted PS was high and overload of the screw drive system had occurred at higher values of screw velocity.

Table 4: Values of controllable operating parameters of plasticization process

	back pressure [MPa]				
	4	7	10	16	24
	screw rotation velocity [rpm]				
	154	200	240	286	333
	dwell time [s]				
	8	12	20	30	50
	barrel temperature [$^\circ\text{C}$]				
	140	160	180	200	220
PE-LD	150	170	190	210	230
PE-HD	200	215	230	245	260
PP	-	180	200	220	240
PS	-	-	-	-	-

3. Experimental results and discussion

Four series of experiments were performed: the first group of experiments took into account variable back pressure, the second one was for variable screw speed, the third one was for variable dwell time and the last one was for variable barrel temperature. Due to space constraints, the results for the variable rotational speed of the screw and for the variable dwell time only are shown below.

In the first series, the average power demanded by the heaters placed on the barrel and the average power demanded by the rotating screw for variable back pressure during plasticization of different thermoplastic polymers were determined. Obtained results, along with the throughput of the injection molding process, are

shown in Fig. 5-8. The SEC values for the injection process of different polymers, defined accordingly to the formula (1), are shown in Fig. 9.

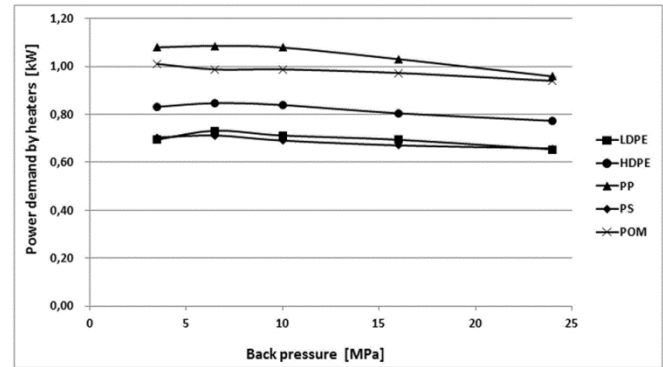


Fig. 5 Power demand by heaters at variable back pressure

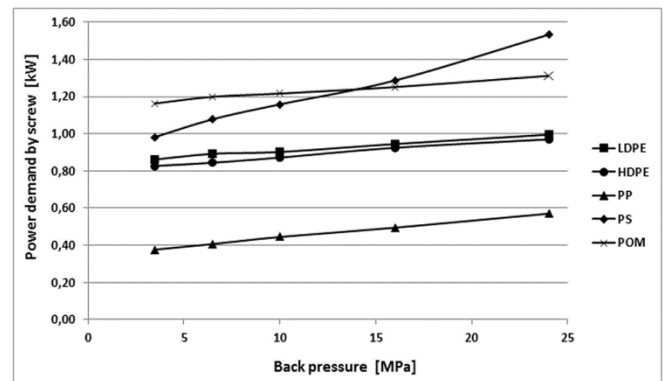


Fig. 6 Power demand by the screw at variable back pressure

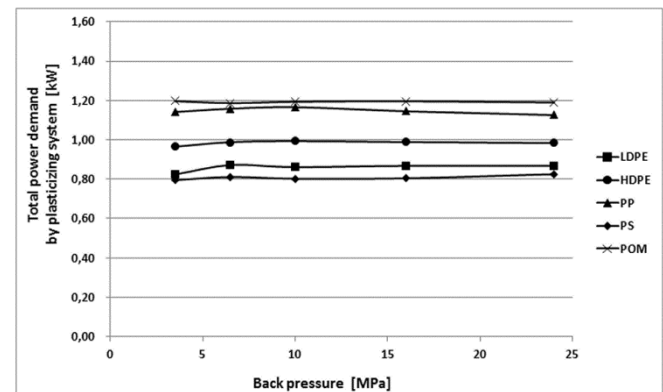


Fig. 7 Total power demand by plasticizing system at variable back pressure

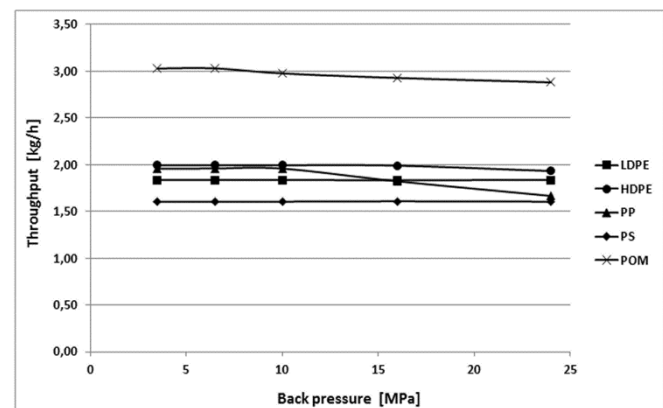


Fig. 8 Throughput of the injection process at variable back pressure

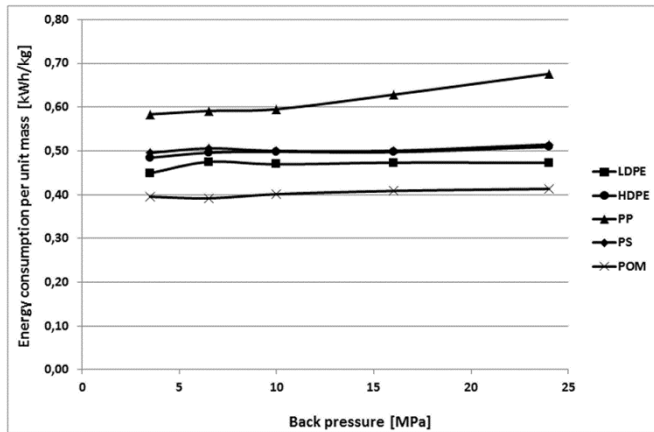


Fig. 9 SEC for the injection process at variable back pressure

Figs. 5-8 show very similar behavior for all tested thermoplastics. By changing back pressure values in the range of 3.5-24 MPa, slight maximum of the power demand by the heaters and slight increase of the average power demand by the screw can be observed. Only for amorphous PS, the power demand by the screw increases quite rapidly with increasing back pressure. Assuming that there are two most important power components mentioned above, i.e. the average power demanded by the screw and the average power demanded by the heaters, the approximate total power demanded by the plasticizing system of injection molding machine does not practically change with increasing back pressure. On the other hand, due to the constant throughput of the injection molding process for the whole range of back pressure values it can be seen in Fig. 9, that the SEC remains constant with the exception of PP, where the SEC grows about 20% for back pressure changes in the range of 3.5-24 MPa as a result of throughput decreasing. However, the different behavior of PP may be associated with the different melting mechanism. It could be related to high degree of crystallinity of solid PP and/or with crystals rearrangement during fusion [17,18]. The different behavior of PP during the melting process could be also observed in work concerned with starve feeding in extrusion process [19].

The results show that the injection molding process on the research position should be performed at the higher back pressure values, because on the one hand, it promotes improvement of material and thermal homogenization of molten polymer in the barrel. On the other hand, the increase in back pressure does not practically affect throughput and power demand by the plasticizing system, that is crucial in the entire LCI for the injection molding process.

The next experiment involved measurements of characteristics of the injection molding process at variable screw rotation velocity. Measurement results of power characteristics and process yield are shown in Figs. 10-13. The SEC for the injection molding process for various thermoplastic polymers at different values of screw rotation speed is shown in Fig. 14.

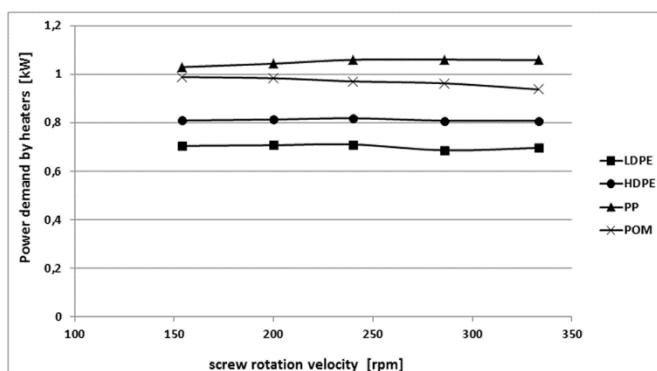


Fig. 10 Power demand by heaters at variable screw rotation velocity

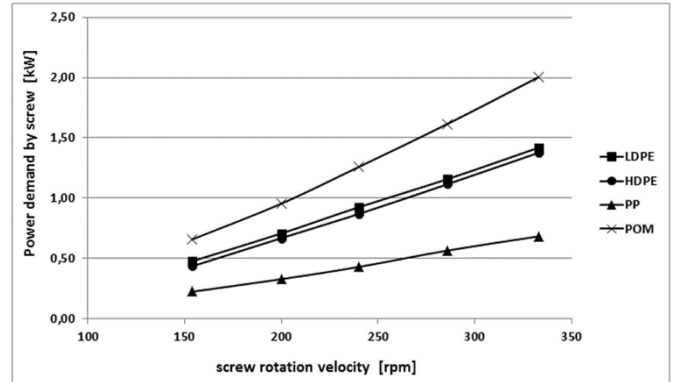


Fig. 11 Power demand by the screw at variable screw rotation velocity

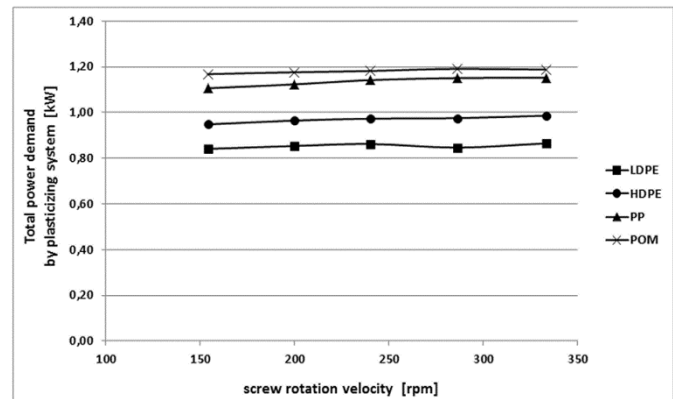


Fig. 12 Total power demand by plasticizing system at variable screw rotation velocity

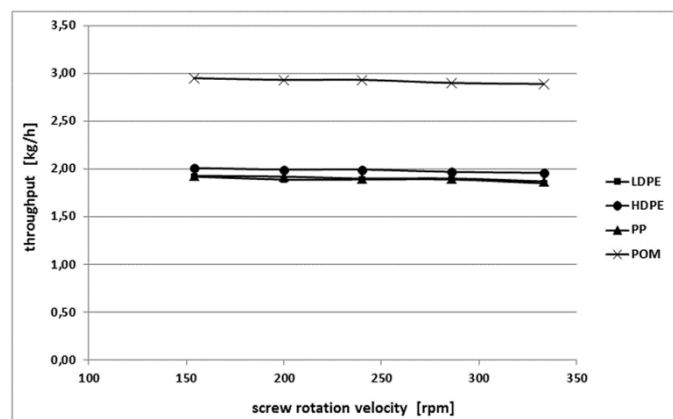


Fig. 13 Throughput of the injection process at variable screw rotation velocity

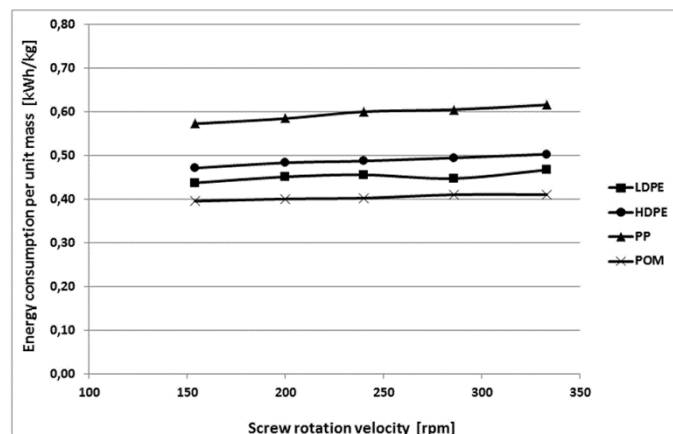


Fig. 14 SEC for the injection process at variable screw rotation velocity

There is practically no impact of variable rotational velocity of the screw on the power demand by heating elements (Fig. 10) for all investigated polymers. At the same time, a significant increase of the average power demand by the screw can be seen (Fig. 11). This leads to a mild growth of the total power demand by the plasticizing system with increasing rotational velocity of the screw, regardless of the type of polymer. Because of the constant yield characteristics (the rotation time of the screw is a part of the cooling time and has no impact on the yield of the injection molding process) with rising screw velocity, it can be seen in Fig. 14 that the SEC increases slightly. It follows that the injection molding process should be carried out at the low to medium values of the rotational screw velocity. High values of the screw speed result in the increased SEC till approx. 10% for the highest screw speed. Of course, the increasing power demand values by the screw for increasing rotational speed are compensated by the decreasing rotation time of the screw. It is result of the $(P_s \cdot t_r)$ term in formula (2). Hence, the effect of the power demanded by the screw on the SEC is very small.

In conclusion, lower screw velocity values give less power demand by plasticizing process and, due to the constant throughput values, lower SEC values. These differences in the SEC values, however, are small. At the same time it is worth noting that it is not recommended to perform the injection molding process with high values of the rotational velocity of the screw. In this case, the circumferential speed is rather more important than the rotational one. With the large circumferential speed, a probability of a thermal decomposition of some polymer materials grows especially for the processing of more thermally sensitive materials such as PVC, polymer blends, thermosets and elastomers [20].

4. Conclusions

The injection molding process is a very widespread method of polymer processing, for which the annual, global energy consumption is comparable to the annual energy production of different European countries. The most energy-consuming stage is the plasticization process which needs the energy for reciprocating screw motion and heating of the barrel. In this work both the issues were examined by changing various working parameters of the injection molding process, measuring the corresponding process characteristics and calculating relevant values of the SEC (specific energy consumption). Five thermoplastic polymers (PE-LD, PE-HD, PP, PS and POM) were examined. It was found that the optimal conditions to perform the plasticization of thermoplastic polymers on the research position [15] were obtained when the low rotational screw velocity was applied. An increase of the SEC value with increasing barrel temperature was shown. It was ca. 15% for the barrel temperature rise by 20°C. It was also found that back pressure changes do not affect the power demand by the plasticizing system of the injection molding machine.

The strength measurements were not performed in this study. We focused only on power demand. The range of variable process parameters was assumed to obtain the correct quality of the moldings without shrinkage and other visible defects. It is worth to compile the proposed directions of changes in the values of technological parameters of the injection molding process with the mechanical properties of the received products. Then we can make a full analysis of the profitability of changes of technological parameters mentioned above.

Summarizing, it has been shown that the process of injection molding for thermoplastics should be performed at relatively low values of screw rotational velocity and large values of back pressure, as well as short values of dwell time for minimizing the energy consumption under the above experimental conditions. It is worth to perform similar research for larger injection molding machines and geometrically various moldings to generalize or detail the results presented in this work.

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