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ECOLOGICAL COSMETIC PACKAGING: USE OF BIODEGRADABLE POLYMERS

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ECOLOGICAL COSMETIC PACKAGING: USE OF BIODEGRADABLE POLYMERS

EKOLOGICZNE OPAKOWANIA KOSMETYCZNE: WYKORZYSTANIE BIODEGRADOWALNYCH POLIMERÓW

***Summary**: Traditional plastic packaging used in the cosmetics industry constitutes a significant burden on the environment due to its limited recyclability and long degradation time. In response to this problem, an alternative solution was developed in the form of biodegradable polymer packaging. This work presents the process of creating a safe and functional packaging for cosmetic masses, which is biodegradable under industrial composting conditions. The research included the development of an appropriate polymer composition, analysis of its mechanical and barrier properties, assessment of biodegradability and safety in contact with cosmetic products. Additionally, tests were carried out to optimize the production process and a series of packaging meeting the appropriate requirements were developed. The effect of the work carried out was to obtain a material with functional parameters that also meets environmental standards. The effectiveness of the developed solution was confirmed by obtaining appropriate certificates and a patent for the invention, which proves the innovativeness and implementation potential of the new type of biodegradable cosmetic packaging.*

***Keywords**: polylactide, biodegradation, mechanical properties, cosmetic packaging*

Streszczenie: Tradycyjne opakowania z tworzyw sztucznych stosowane w przemyśle kosmetycznym stanowią istotne obciążenie dla środowiska ze względu na ich ograniczoną możliwość recyklingu i długi czas degradacji. W odpowiedzi na ten problem opracowano alternatywne rozwiązanie w postaci biodegradowalnych opakowań polimerowych. Niniejsza praca przedstawia proces tworzenia bezpiecznego i funkcjonalnego opakowania na masy kosmetyczne, które ulega biodegradacji w warunkach kompostowania przemysłowego. Badania obejmowały opracowanie odpowiedniej kompozycji polimerowej, analizę jej właściwości mechanicznych i barierowych, ocenę biodegradowalności oraz bezpieczeństwa w kontakcie z produktami kosmetycznymi. Dodatkowo, przeprowadzono testy nad optymalizacją procesu produkcji oraz opracowano serię opakowań spełniających odpowiedzenie wymagania. Efektem przeprowadzonych prac było uzyskanie materiału o parametrach użytkowych, który jednocześnie spełnia normy środowiskowe. Skuteczność opracowanego rozwiązania potwierdzono poprzez uzyskanie stosownych certyfikatów oraz patentu na wynalazek, co dowodzi innowacyjności i potencjału wdrożeniowego nowego typu biodegradowalnych opakowań kosmetycznych.

Słowa kluczowe: polilaktyd, biodegradacja, właściwości mechaniczne, opakowania kosmetyczne

Introduction

Polymer packaging plays an extremely important role in the cosmetics industry. It is used not only to store and protect products, but also plays a key marketing role, influencing consumer purchasing decisions. The modern cosmetics industry strives to use materials that combine high aesthetics and durability with ecological aspects. Traditional synthetic polymers, although they provide excellent protection for cosmetics, pose a significant burden on the environment, especially as post-consumer waste [1–5].

In the face of growing ecological awareness and restrictive legal regulations, more and more attention are being paid to biodegradable polymeric materials [6-10]. Their use in cosmetic packaging is a compromise between durability and protection of the product and reduction of the negative impact on the environment after the end of the packaging life cycle. Among biodegradable polymers, polylactide (PLA) occupies a special place, being one of the most promising materials in this field [11–13].

Polylactic acid (PLA) is a biodegradable polymer obtained from renewable raw materials such as corn starch, sugar cane or sugar beet. It is one of the most promising biopolymers, used in many industries, including cosmetic packaging, medicine, food and textiles [14–16]. It decomposes in industrial composting conditions, transforming into water, carbon dioxide and biomass, creating a closed circle, as it is produced from plants, which reduces the dependence on fossil fuels. It does not contain toxic substances and is approved for contact with food and cosmetics. It can be used to produce elegant, transparent packaging with high visual quality. It shows strength similar to traditional plastics, although it is more brittle [17–18].

Polylactide (PLA) is naturally resistant to fats and oils, making it an attractive material for use in the cosmetics and food industries. However, its barrier against the penetration of chemicals, both from the inside of the package to the outside and vice versa, is limited [19–22]. In order to improve the barrier properties of PLA, various modification methods are used, such as: addition of fillers and nanofillers, coating with protective layers, chemical modifications or co-polymerization by introducing additional monomers, increasing its hydrophobicity of PLA, reducing the penetration of moisture and organic substances. Such treatments significantly worsen its biodegradability [23–25]. It is necessary to find a compromise between the durability of the packaging and its degradation after the end of its use. With appropriate modifications, PLA can achieve properties similar to conventional plastics, while maintaining biodegradability and compliance with ecological standards.

The purpose of the work was to develop a material for cosmetic packaging that is biodegradable under industrial composting conditions. This was a significant challenge due to the specific and difficult to achieve criteria both as packaging for the cosmetics industry, but also maintaining the biodegradability of such a material.

Materials and research methodology

Several types of polylactides with different parameters and properties from NatureWorks were used for preliminary studies. Other biodegradable polymer materials were used as modifiers in preliminary studies. Among others, the group of polyhydroxyalkanoates (PHA), belonging to the group of aliphatic polyesters, built from one hundred to several thousand hydroxy acid residues. They are characterized by a large variety of monomer structures. They are produced by bacteria in the fermentation process of sugars or lipids as a reserve material. The prepared mixtures of these two polymers were not problematic in the processing process, but they did not meet the requirements related to the migration of the reference substance from the packaging to the material. Such composites would not be a barrier for cosmetic masses [26-27].

Similar tests were performed with PHBV Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) is a polyhydroxyalkanoate type polymer. It is a biodegradable, non-toxic, biocompatible polymer produced naturally by bacteria and a good alternative to many non-biodegradable synthetic polymers. It is a thermoplastic linear aliphatic polyester. It is obtained by copolymerization of 3-hydroxybutanoic acid and 3-hydroxypentanoic acid. PHBV is used in specialist packaging, orthopedic devices and in controlled drug release. PHBV undergoes bacterial degradation in the environment [28-30].

To optimize the functional properties of polylactide (PLA) and maintain its biodegradability, calcium carbonate ($CaCO_3$) was added as a filler. Calcium carbonate is widely used in traditional polymer materials due to its numerous beneficial properties, such as improved processability, dimensional stability and barrier properties of the material [31-34]. Moreover, its use allows for reducing production costs, which is an important aspect when implementing biodegradable polymers as alternatives in the packaging industry. Ready-made calcium carbonate concentrates are available on the market in the form of concentrates (masterbatches), which can be easily dosed to the polymer during processing. However, in this case it was necessary to use calcium carbonate in the form of a powder with a precisely selected structure. The key aspect was to control the size and shape of the particles to ensure their uniform dispersion in the PLA matrix, which prevents aggregation and negative impact on the mechanical and optical properties of the material [35-38].

Additionally, the selection of the appropriate $CaCO_3$ concentration was important from the point of view of maintaining the biodegradability of the entire system. Excessive amounts of non-degradable filler could limit the rate of material decomposition in composting conditions. The optimal weight share of calcium carbonate allowed for maintaining a balance between improving the functionality of the packaging and its biodegradability at the end of its life cycle. Calcium carbonate from OMNIA (Switzerland) was used in this work [39-40].

The tests carried out with direct introduction of the filler into the plastic on an injection molding machine equipped with a feeder did not cause any problems, because the maximum filling was 10% wt. However, tests of the material structure showed uneven distribution of particles. Therefore, it was necessary to prepare the material in advance on an extruder. For this purpose, a twin-screw extruder was used [41].

The decisive factor here was the research on ready-made containers with cosmetic mass. Despite meeting several criteria, there was still a problem with the migration of the reference substance (cosmetic mass) into the material. A slight loss of mass was also observed, but definitely smaller than in the previously discussed cases.

The solution that gave positive results was the use of an aromatic carbodiimide-based additive in PLA with calcium carbonate [41-42]. Carbodiimides are a group of organic compounds containing a characteristic functional group –N=C=N–, which are widely used as condensing agents in coupling reactions, e.g. in peptide synthesis and in polymer modification. Their unique chemical properties, including the ability to bind water molecules, mean that they have been used as stabilizers in biodegradable materials, where controlling interactions with water is crucial [43-45].

The use of aromatic carbodiimides in this system allowed for the optimization of the compromise between the durability and biodegradability of the material. On the one hand, the resistance to external factors was increased, which is important for the functionality of cosmetic packaging, and on the other hand, the possibility of degradation in appropriate industrial composting conditions was preserved. Additionally, an important aspect was the adjustment of the amount and type of carbodiimide used. An excessive amount could lead to a significant reduction in biodegradation, making the material less ecological, while too low an additive level would not provide sufficient protection against moisture. Therefore, it was necessary to select the appropriate concentration, which would allow for effective protection of the polymer structure, while not interfering with its ability to biodegrade after the end of its life cycle.

All PLA additives were introduced in the twin-screw extrusion process. This method of production guaranteed obtaining a homogeneous material. Carbodiimide with the trade name Stabaxol P110, available in powder form, was used in the tests as well as in later works [46-47].

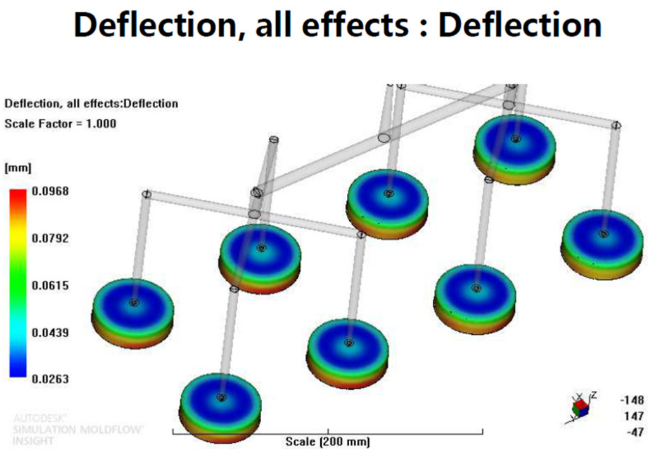
Ultimately, after optimizing the individual components, we managed to develop a PLA-based material that underwent tests both in terms of mechanical properties and in terms of assessing the process of interaction between the cosmetic mass and the packaging.

Construction of tools (injection molds) for complete packaging

In parallel with the work on refining the composition of the polymer composition, work was underway on the design of tools and injection molds for the production of complete packaging in the form of a jar with capacities from 0.25 dcm^3 to 0.50 dcm^3. It was necessary to design injection molds for the jar and for the lid with a thread. The problem to be solved was to determine the compatibility of the jar and lid threads. It resulted from material shrinkage.

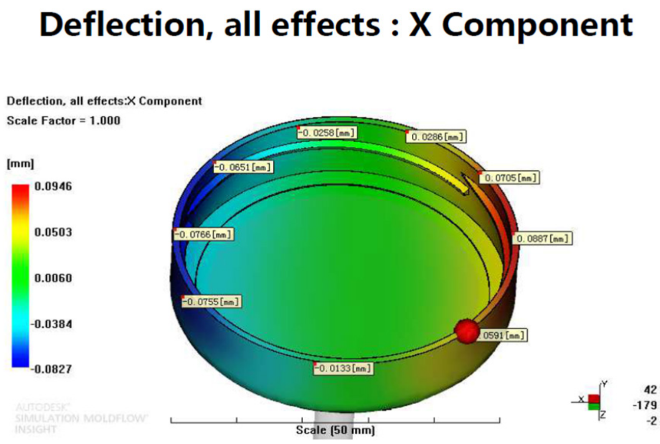
In order to eliminate defects at the design stage, MoldFow software was used. Figures 1 to 5 show the subsequent stages of analysis of the results obtained during simulation.

The obtained simulation results taken into account in the modeling of the injection molding process were a valuable hint for designers and technologists during the process design. They also allowed for the selection of optimal process parameters to



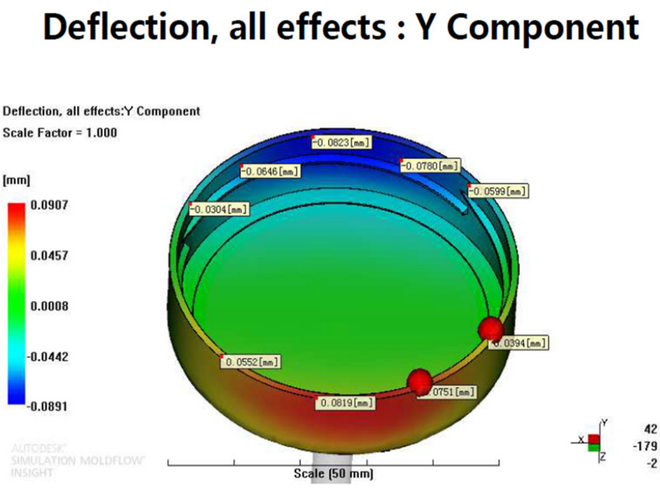
The deflection include uniform shrinkage.	
The scale of deflection	1
Total deflection value (mm)	0.0968

Fig. 1. Distribution of nests in the injection mold



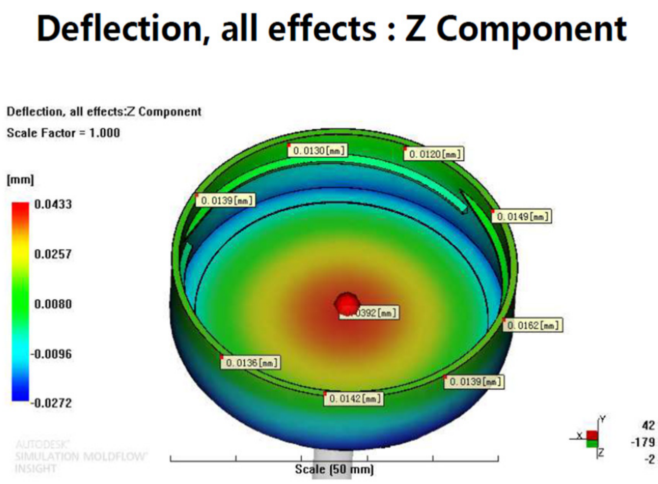
The deflection include uniform shrinkage.	
The scale of deflection	1
The deflection value of X component (mm)	-0.08~0.09

Fig. 2. Process simulation



The deflection include uniform shrinkage.	
The scale of deflection	1
The deflection value of Y component (mm)	-0.08~0.09

Fig. 3. Injection simulation, part II



The deflection include uniform shrinkage	
The scale of deflection	1
The deflection value of Z component (mm)	-0.02~0.04

Fig. 4. Injection simulation, part III

obtain the required quality of the part and to reduce the number of attempts to correct the mold and machine parameters. Figures 6 and 7 show photos of the manufactured jar and lid.

Conclusions & Suggestions

Results	Case
Fill status	Good
Range of temperature at the flow front (°C)	161-181
The max. pressure value (Mpa)	95.47
The max. Clamp force value (tonne)	95.77
Weld lines	No
Serious air traps	No
The deflection is normal or not for this product	Yes

Fig. 5. Injection simulation – summary

Fig. 6. Photos of the finished jar and lid

Fig. 7. Complete package

Conclusions

The use of biodegradable polymeric materials, such as polylactide (PLA), is a significant step towards the sustainable development of the cosmetics industry, and in particular for the production of packaging. The combination of high-quality packaging with minimal impact on the environment allows to meet the expectations of both consumers and legal regulators. Despite the challenges related to costs and infrastructure, the dynamic development of this technology gives hope for the widespread implementation of biodegradable packaging in the future. The best recommendation of the conducted work was the confirmation of the properties of the material and packaging through obtained certificates [48, 49] and the patent for the invention No. PL 244616 [50].

The work was carried out as part of the NCBIR project "Development of technology for manufacturing new biodegradable packaging from biopolymers for the cosmetics industry" in the period from 01.01.2018 to 31.12.2022 under Measure 1.1: R&D projects of enterprises of the Smart Growth Operational Program 2014–2020 co-financed by the European Regional Development Fund no. POIR.01.01.01-00-0846/17-00.

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METHODOLOGY OF BACKCASTING OF MANUFACTURING PROCESS ON THE EXAMPLE OF IMPLEMENTATION OF ADVISORY SYSTEMS IN MANUFACTURING PROCESSES

METODYKA WSTECZNEGO PROGNOZOWANIA PROCESU PRODUKCYJNEGO NA PRZYKŁADZIE WDROŻENIA SYSTEMÓW DORADCZYCH W PROCESACH PRODUKCYJNYCH

***Summary**: In the present paper, the methodology of the backcasting of manufacturing process and the possibilities of the application of Bizagi Modeler software with the utilization of BPMN notation with the aim to show the analyzed manufacturing processes in the conceptional aspect was submitted. As the example, the problem of the choice of filament in the incremental manufacturing process and the issue of selection of semi-fabricate in the machining process were discussed. The implementation of advisory systems based upon the simulation model in Flexsim software with the application of method of backcasting was analyzed. In the conducted simulation, the times for two analyzed variants in the both mentioned above manufacturing processes were compared. The first variant considered the employment of advisory systems and the second one assumed the standard run of the process, with the verification of senior technologist.*

***Keywords**: advisory systems, 3D print, machining, simulation modeling*

Streszczenie: W rozdziale przedstawiono metodykę wstecznego prognozowania procesu produkcyjnego oraz możliwości wykorzystania oprogramowania Bizagi Modeler z wykorzystaniem notacji BPMN w celu przedstawienia analizowanych procesów produkcyjnych w ujęciu koncepcyjnym. Jako przykład w rozdziale wykorzystano problem doboru filamentu w procesie wytwarzania przyrostowego oraz problem doboru półfabrykatu w procesie obróbki skrawaniem. Wdrożenie systemów doradczych przeanalizowano w oparciu o model symulacyjny w oprogramowaniu Flexsim z wykorzystaniem metodyki wstecznego prognozowania.

Słowa kluczowe: Systemy doradcze, druk 3D, obróbka skrawaniem, modelowanie symulacyjne

Introduction

At the present era of Industry 4.0, manufacturing companies introduce, more and more frequently, the advanced computer-based technologies with the aim to organize the production processes in the more effective way. The mentioned technologies are based on the assumptions of Industry 4.0 which emphasizes the integrated digital systems, enabling the automation of processes in the enterprise, *inter alia*, such as management of manufacturing knowledge in a wide range and where the computer simulations are one of the pillars of the discussed idea [5]. Modelling of manufacturing processes is a key issue for introduction of the technology of digital twins within the frames of digital transformation which is also assumed by the conception of Industry 4.0 [1]. Simultaneously, the failures are often encountered in the production environment and the incorrect sequence of manufacturing operations connected with the planned and real material flows is met. To minimize the mentioned faults, and to increase the effectiveness of manufacturing processes, it is necessary to employ the methods of simulation modeling [2].

Striving at implementation of lean manufacturing based on the conception of Industry 4.0 has become not only a strategic priority but actually a condition necessary (sine qua non) for survival and development of enterprises in the contemporary dynamically varying environment. Integration of the advanced digital tools such as simulation modeling and data processing is a key pillar of the fourth industrial revolution. The mentioned modern technologies not only facilitate the improvement of the manufacturing processes by the enterprises but also affect the abbreviation of the time of decision undertaking. Owing to this fact, the enterprises can more effectively react to the varying needs of the market, minimizing the wastage of resources and increasing their competitivity at a global scale [5].

Simulation modeling of processes is a current effective tool, serving the recognition and illustration of economic phenomena [3]. Dynamically varying micro- and macro-environment of manufacturing companies and a very high level of competitivity forces seeking for the solutions, determined by the market requirements [6]. At present, the manufacturing companies must constantly adjust themselves to the requirements of the customers and varying conditions. It affects, in turn, the abbreviation of the life cycle of products and creates the background for initiating the new production. The manufacturing enterprises have to show the flexibility and, at the same time, maintain the costs at the profitable, relatively low level as to be able to react quickly to the varying requirements of the customers [7].

Simulation modeling in manufacturing processes

Simulation of the manufacturing processes is an important approach to understanding the multidimensionality of real and abstractive systems on the plane of manufacturing processes. Development of simulation model allows the presentation of the crucial features of the system [10] which may be – later on – utilized in the implementation of the improvements in manufacturing processes, being analyzed in the present paper. The simulation in work [1] is defined as the imitation of the action of a real world, process or system in a defined time. Modeling of manufacturing processes is a very important instrument in the context of efficient and effective management of manufacturing enterprise [3]. The implementation of simulation modeling and reverse prognosing (backcasting) is a method of analysis of alternative states of the future which may be employed, *inter alia*, in the technology development. The discussed foresight methodology is characterized by a reversed logics of concluding. It is commenced from the definition of the vision of the future which is assumed to be achieved successively, step by step, withdrawing to the contemporary state [9]. Contrary to the traditional prognosing (forecasting) which anticipates the future events on the grounds of the present trends, backcasting is commenced from the future and serves for development of activities and strategy which may change the current state of things towards the specified goal.

In the paper[1] the simulation model of flexible manufacturing system has been developed. Designing of manufacturing systems which meet the production requirements as well as the market needs has become a greater and greater challenge due to variability of demand on a big number of products in many variants and short periods of implementation. The flexibility of production is universally recognized as the proven solution allowing to reach and maintain the strategic as well as operating goals of the enterprises endangered to a global competition. The general simulation model of flexible manufacturing system has been developed by the authors using Flexsim software and then, the authors utilized the exemplified data for demonstration of the developed model [1].

The application of computer software allows creation of models of the manufacturing processes and introduction of changes in them without the necessity of stopping the implementation of the current tasks. We may conduct the successive simulation on a studied model, changing the input data or arrangement of machines and improve it. At present, the simulations are used in modeling of the products and total manufacturing processes; during the nearest coming years, the employment of simulation software will be increased, with the enlargement of the range of its application in the successive domains. The simulations facilitate conducting of the tests before the changes are introduced in a real manufacturing environment. It should be mentioned that construction of correctly functioning model of manufacturing system is labour-consuming and requires a good knowledge of the process to be modelled as well as simulation software [8]. Moreover, the quality of the model is affected by the level of detailedness of mapping. The application of Flexsim software is the appropriate instrument for modeling and simulation of events.

The solution of technical problems, using simulation modeling is effective and its effectiveness was confirmed in scientific developments (*inter alia*, 10, 11]. The researchers state in their work [12] that correctly designed manufacturing process may have an influence on reduction of operating costs in the manufacturing company even up to 50%. The crucial instruments in

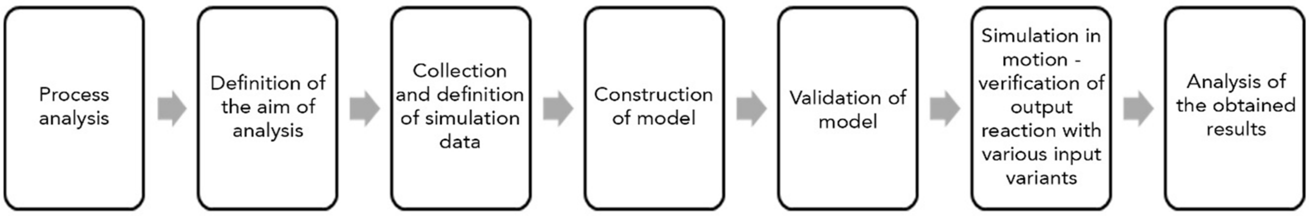

Fig. 1. Run of simulation modeling (own development based on [10])

simulation software serve for modeling of possible scenarios without the necessity of interrupting the on-going production, for visualization of information and analysis of the simulation data [10]. Designing with the employment of the backcasting method is possible owing to utilization of knowledge on the past events. The analysis of the available solutions may derive from the analogical cases, or from the known external potential improvements [14]. Modeling of manufacturing processes, objects and phenomena brings, in effect, obtaining the results in a form of time relationships of statistical data [13]. The run of simulation modeling with the application of backcasting methodology is possible to be presented in a few basic steps [10] as given in Fig. 1.

Application of simulation modeling in manufacturing processes, as analyzed on the example of implementation of advisory systems

Analysis of the lean manufacturing process

To analyze the change i.e. the introduction of advisory system into the machining process, it the scheme of the process run has been given below (Fig. 2). It was shown at the stage of technological designing at technological department in the process aspects, where the junior technologist may take the advantage from the advisory system support. In the authorial assessment of the case, the implementation of the advisory system with the aim to choose a semi-fabricate in the machining process is an innovative solution which contributes to the betterment of manufacturing processes, cost reduction and improvement of the quality of final products. The application of advisory system was highlighted in details at the first stage which includes development of technological processes for the machined parts of the equipment; at this stage, its componential parts were submitted in a simplified way for the needs of visualization of the total process in BPMN notation; it is commended from the choice of semi-fabricates; then, the less experiences worker of technological department has the possibility to consult the assumptions with the more experienced worker; he may also choose, in parallel, the advisory system in which the expert knowledge is recorded. Utilization of the advisory system at the mentioned stage abbreviates considerably the duration time of the whole process and supports meaningfully decision-undertaking by the employee who has a smaller experience. After the choice of the semi-fabricate for production of machine parts, the choice of the machining methods takes place and then, successively, the development of the process structure or machining processes, depending on the complexity of a given product, is carried out.

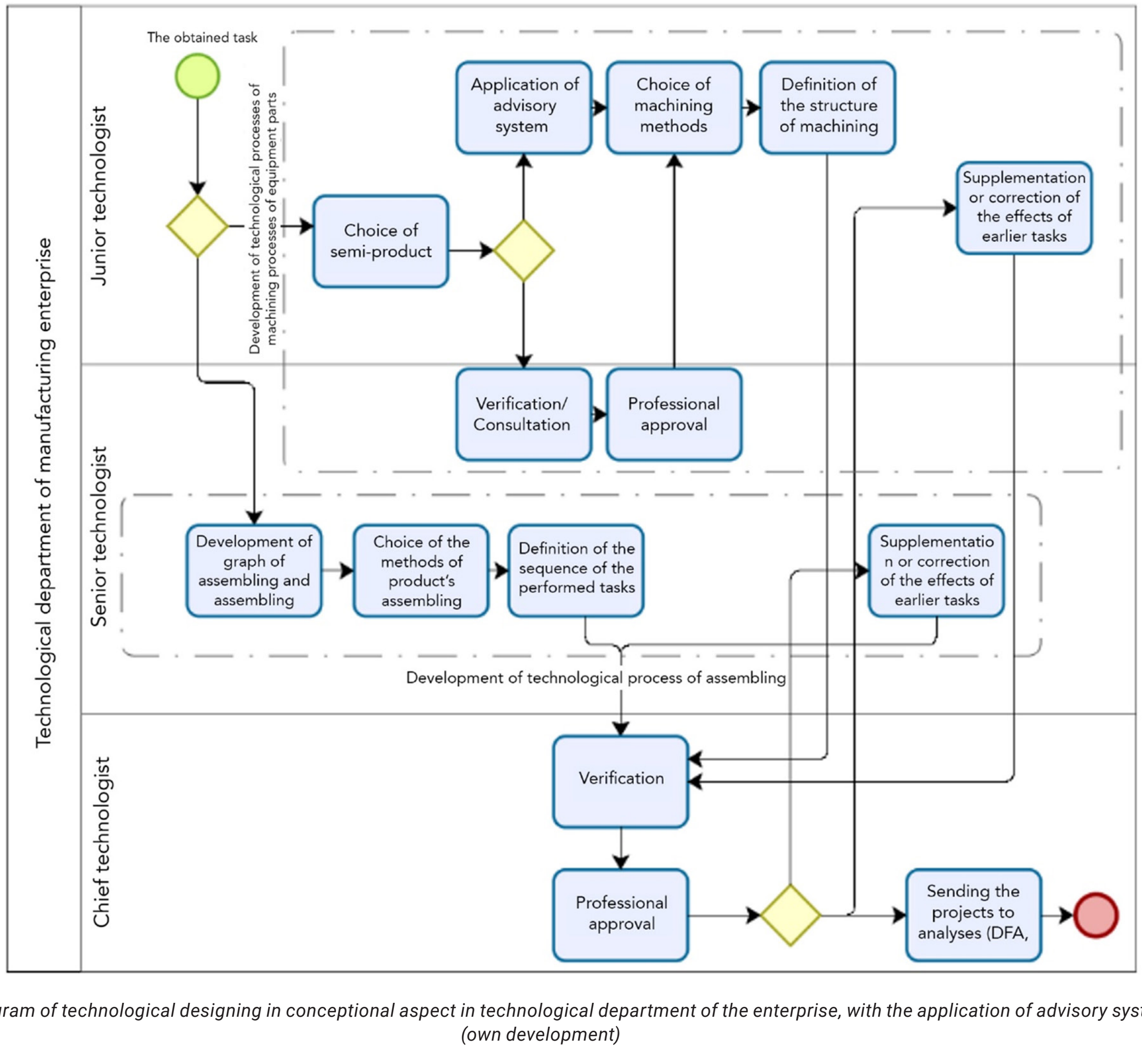

Fig. 2. Diagram of technological designing in conceptional aspect in technological department of the enterprise, with the application of advisory system (own development)

In parallel to the tasks, performed by the junior technologist, the senior technologist develops graph and assembling structure, chooses the assembling methods appropriate for a given product and determines the sequence of performing the set tasks. After termination of the mentioned stages, the verification and professional approval are carried out by the chief technologist; in the case of any irregularities, he sends the effects of the earlier tasks to be complemented or corrected, with the recommendations of sending to the repeated verification. After collection of the developed variants of machining process and implementation of assembling process, the final operation of the discussed stage of manufacturing process (what determines the effect of the total sub-process) includes sending the obtained effects to analyses (for example, the following analyses may be carried out: DFS, DFE, DFR, DFA of DRM). The mentioned above analyses are most frequently implemented as feedbacks and, first of all, they have to serve for the evaluation of constructional solutions of the product, suggested by the workers of technological department as the schemes of ready-to-use technological operations.

Apart from analyzing the run of the process alone, the assessment of the manufacturing process effectiveness may also utilize many indicators. To carry out the analysis of effectiveness in a proper way, the decision and selection of the appropriate indicators should be undertaken on the grounds of consultations with the employees of the enterprise, engineers and managers of the specific departments and also, based on the conducted analyses concerning the manufacture, distribution and sale range, with the consideration of priority tasks, The set of the considered indicators can be modified according to the needs of manufacturing process and the enterprise itself due to the current needs.

When applying the effectiveness indicators, it is possible to differentiate two main groups of the mentioned parameters – financial and non-financial ones which may be referred to the same manufacturing process but also, incomes and costs which are related to a given process [15]. Moreover, the analysis of the effectiveness of manufacturing processes allows distinguishing the weak and strong points of manufacturing processes.

The application of advisory system which supports undertaking of decisions concerning the choice of semi-fabricates for machining, affects the abbreviation of the time of implementation of the contract. A precise estimation of how much the total time of the implementation of the order may by decreased and how much the time of production of one element may be shortened, will be dependent on many factors, *inter alia*, such as number and complexity of the elements, availability of appropriate tools and machines and, also the competence of the workers of the particular departments.

The studies carried out at the enterprise revealed that the introduction of the changes in manufacturing process has brought about the increase of effectiveness. Based on the simulation data, it is estimated that the mean time of the implementation of the orders was decreased by 10% what means that the enterprise is capable to serve higher number of orders at a shorter time. The simulations were conducted basing on the time of the implementation of the order without application of advisory system and they were compared to the variant with the application of the advisory system. The produced simulation

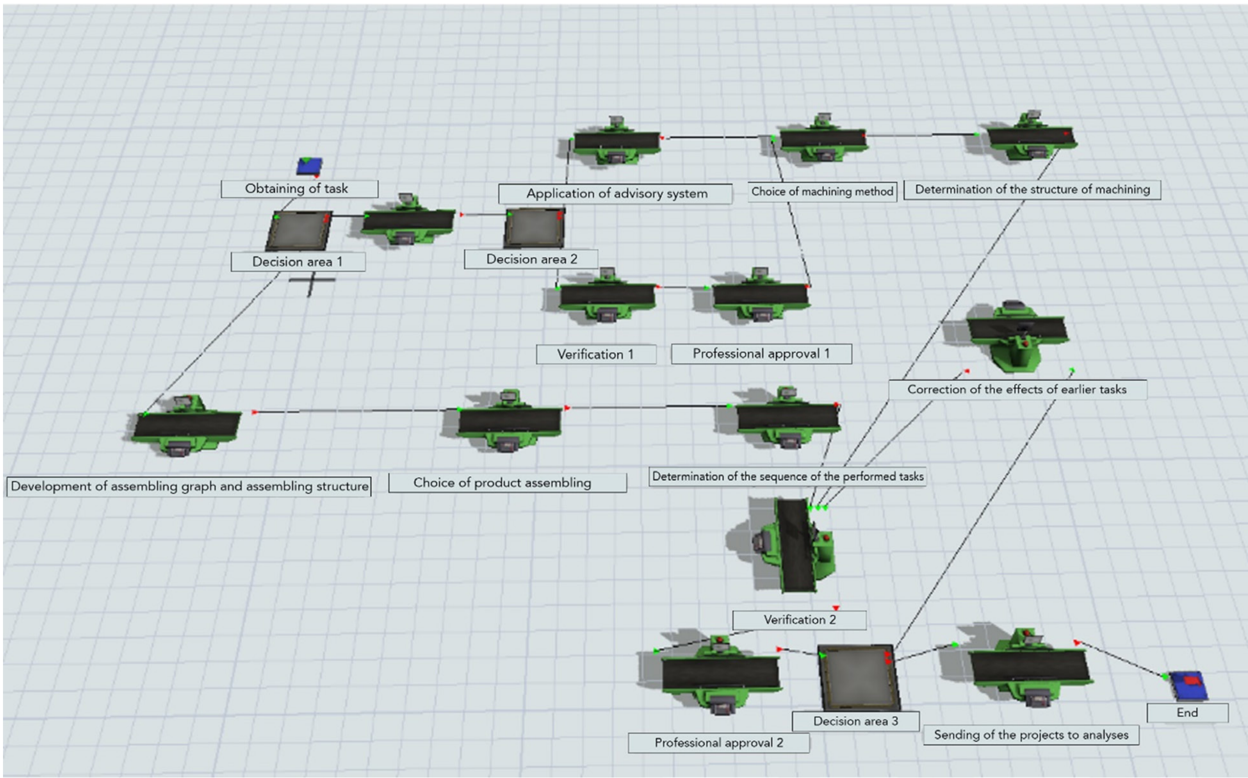

Fig. 3. The example of the simulation model in Flexsim environment for machining process (screenshot developed in cooperation with Mr. Mateusz Gacek)

models of manufacturing process in two variants – without the advisory system and with its application – should consider all stages of the manufacturing process, the time necessary for the performance of each stage and the time of waiting for the resources. The exemplified simulation system, developed in FlexSim environment, in cooperation with Mr. Mateusz Gacek for the machining process is given below (Fig. 3).

The average duration of the simulated process was decreased by more than 10% when using the variant with the advisory system, based on the simulation model times of the processes in the both variants (Table 1 and Table 2).

It is especially significant for manufacturing enterprises which are specialized in production at order where the time of implementation of the orders is crucial for the satisfaction of the customers and reaching the success on the market. It should be mentioned that although the decline of the time of the order implementation for large-series and mass production was lower, it still remained a meaningful increase of production effectiveness. Owing to it, the enterprise may implement a higher number of orders at a shorter time what leads to gain of profits and improvement of the competitivity at the market.

Table 1. Simulation times [h] for machining process in variant with the application of advisory system

Process	Average process time	Minimum process time	Maximum process time
Choice of semi-fabricates	2,02	1,84	2,26
Verification 1	0,00	0,00	0,00
Application of advisory system	0,25	0,25	0,25
Choice of machining methods	2,01	1,66	2,50
Professional approval 1	0,00	0,00	0,00
Determination of the structure of machining processes	4,01	2,99	5,00
Development of assembling graph and of assembling structure	5,03	4,19	6,06
Choice of the methods for product assembling	3,03	2,55	3,44
Determination of the sequence of the performed tasks	2,00	2,00	2,00
Correction of the effects of the earlier tasks	3,16	2,74	3,46
Verification 2	2,91	0,23	5,00
Professional approval 2	2,28	2,00	3,79
Sending the projects to analyses	0,25	0,25	0,25

Table 2. Simulation times [h] for machining process in variant without the application of advisory system

Process	Average process time	Minimum process time	Maximum process time
Choice of semi-fabricates	2,02	1,84	2,28
Verification 1	1,19	0,98	1,45
Application of advisory system	0,00	0,00	0,00
Choice of machining methods	2,07	1,51	2,40
Professional approval 1	2,28	2,01	4,05
Determination of the structure of machining processes	3,98	2,85	5,12
Development of assembling graph and of assembling structure	4,92	4,27	5,61
Choice of the methods for product assembling	2,98	2,55	3,39
Determination of the sequence of the performed tasks	2,00	2,00	2,00
Correction of the effects of the earlier tasks	2,96	2,30	3,52
Verification 2	2,92	0,59	5,01
Professional approval 2	2,28	2,00	3,30
Sending the projects to analyses	0,25	0,25	0,25

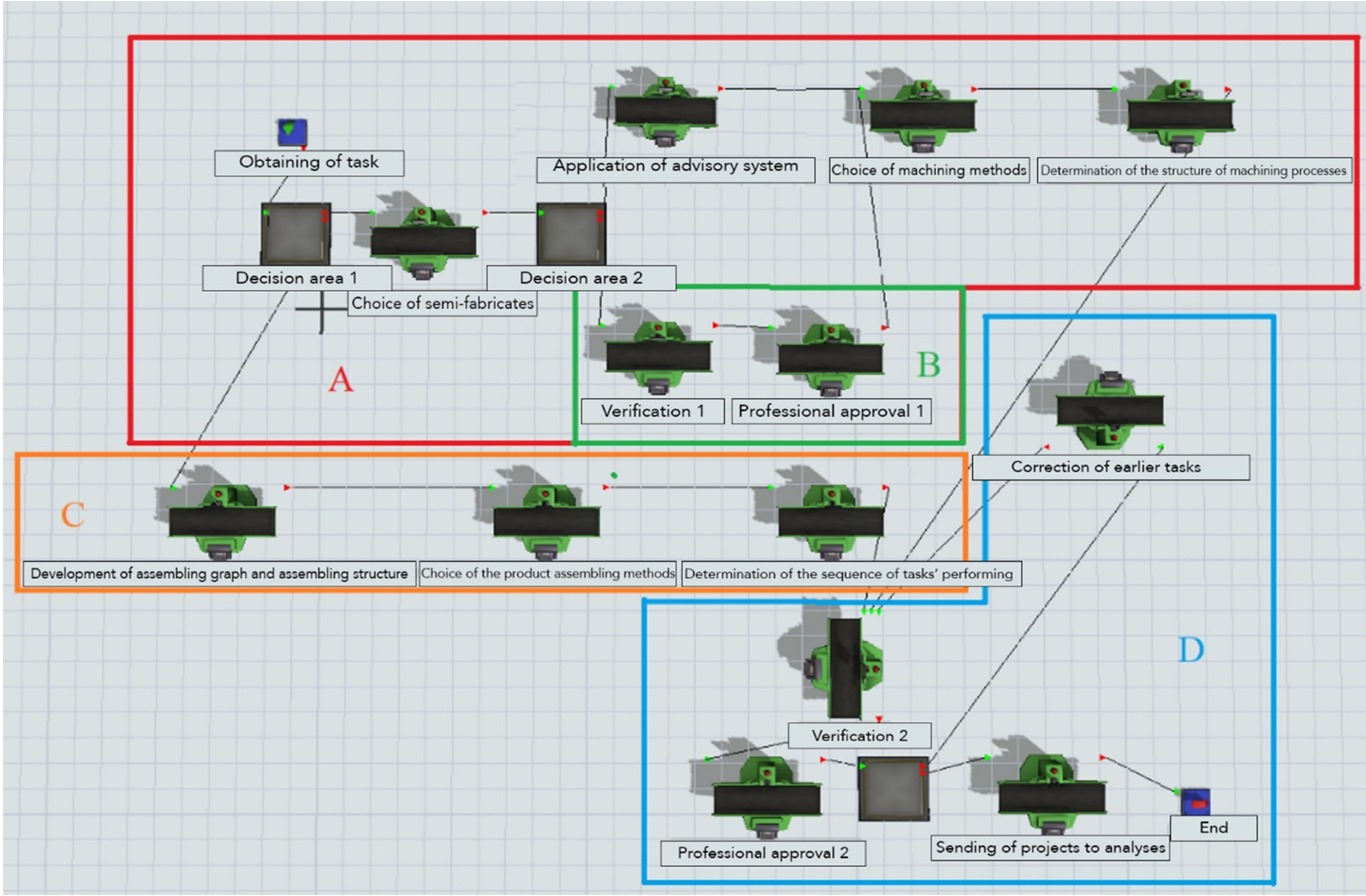

Fig. 4. Division of simulation in Flexsim program into areas (screenshot developed in cooperation with Mr. Mateusz Gacek)

There were presented above the process times for each of the variants which were obtained by 100-times repetition of the process in each configuration. The conducted simulation was divided into 2 variants and 4 area, A, B, C and D, respectively (Fig. 4). The first variant assumed the run of the process with the application of advisory system and concerned the areas A and D, or A, C and D, according to the needs of the implemented order; the division adopted in decision area is 0.5. The second variant concerned areas A, C and D or, analogically to variant 1, A, B and D. The second variant assumed lack of utilization of the advisory system and application of verification by the more experienced technologist. In each of the analyzed cases, a separate run through A, C and D areas was also considered. The mentioned areas are a part of the total analyzed process and its exclusion from the simulation could have a negative influence on the results.

Area A is the area, commencing simulation which begins from the element corresponding to obtaining of the task which is directed, in the further stage, to sector C or remains in area QA. In the case when the order dos not change the area, it is directed to the process of choosing the semi-fabricates and then, to the decision area 2 where the choice is made: verification by the senior technologist, or application of advisory system. If the analyzed task passes the so-called processor (element used in simulation) assuming the utilization of the advisory system, it will go the way via the processors assuming the choice of the machining methods and determination of the structure of machining processes; finally, it comes to area D. Area B will be only activated in variant 2 whereas the order will be directed from area A to area B and then, it will again come to area A and the further procedure will be continued by path A – D. Area C is subordinated to eventual situation when area A and area B are not utilized in simulation. At such case, the order runs via the processors which have been defined as the processes of: developing the assembling graph and assembling structure, choice of the product assembling methods, and determination of the sequence of the tasks' performance. Area D is a connector between areas A and C owing to linking of verification 2 and professional approval 2. In the discussed area, there is also a looping, which may cause delays in a form of correction of the effects of the earlier tasks. If all the operations are approvable and do not require any corrections, or have been approved after the correction, the projects are sent to analyses and the process is terminated. The table given below presents the mean times of both variants and the extrapolated summarized times for 100 processes for the particular variants (Table 3). It allowed to abbreviate the time by 183 hours in 100 events.

In general, however, the application of advisory system is helpful in the abbreviation of the time of the order implementation owing to the decrease of the time necessary for the choice of the appropriate semi-fabricate for machining process, and, also, reduction of the number of errors and elimination of delays,

Table 3. The mean and extrapolated summarized times for 100 iterations (own development)

	Variant I: Application of advisory system	Variant II: Lack of the application of advisory system
Mean time	15,87 [h]	17,7 [h]
Extrapolated summarized time for 100 iterations	1587 [h]	1770 [h]

connected with the improper choice of the semi-fabricate. The precise time by which the order implementation time may be reduced will be dependent on many factors such as complexity of the order, availability of the appropriate semi-fabricates on the market and also, on the effectiveness of the introduced advisory system. Nevertheless, the application of the discussed system contributes to the abbreviation of the time of order implementation by few days or even weeks.

The employment of the advisory system increases the effectiveness of the machining process. Owing to the registered information on the earlier machining operations, such as processing parameters, employed materials and the obtained results, it is possible to avoid the errors and to improve the future operations. It, in turn, leads to the increase of productivity and performance of the machining process.

Analysis of the incremental manufacturing process

Fig. 5 (below) illustrates the run of the process of the choice of filament for incremental production in BPMN notation, in one path with the application of the advisory system; the other one is shown without the application of the advisory system what shows graphically the impact on the abbreviation of the time of the mentioned stage of the manufacturing process. It is also directly manifested in the increase of the analyzed process effectiveness.

The advisory system is the useful tool which affects the abbreviation of the time of the order implementation in the incremental manufacturing process. First of all, the discussed system allows better utilization of the available knowledge, connected with the choice of filament what has a key meaning in the incremental manufacturing process.

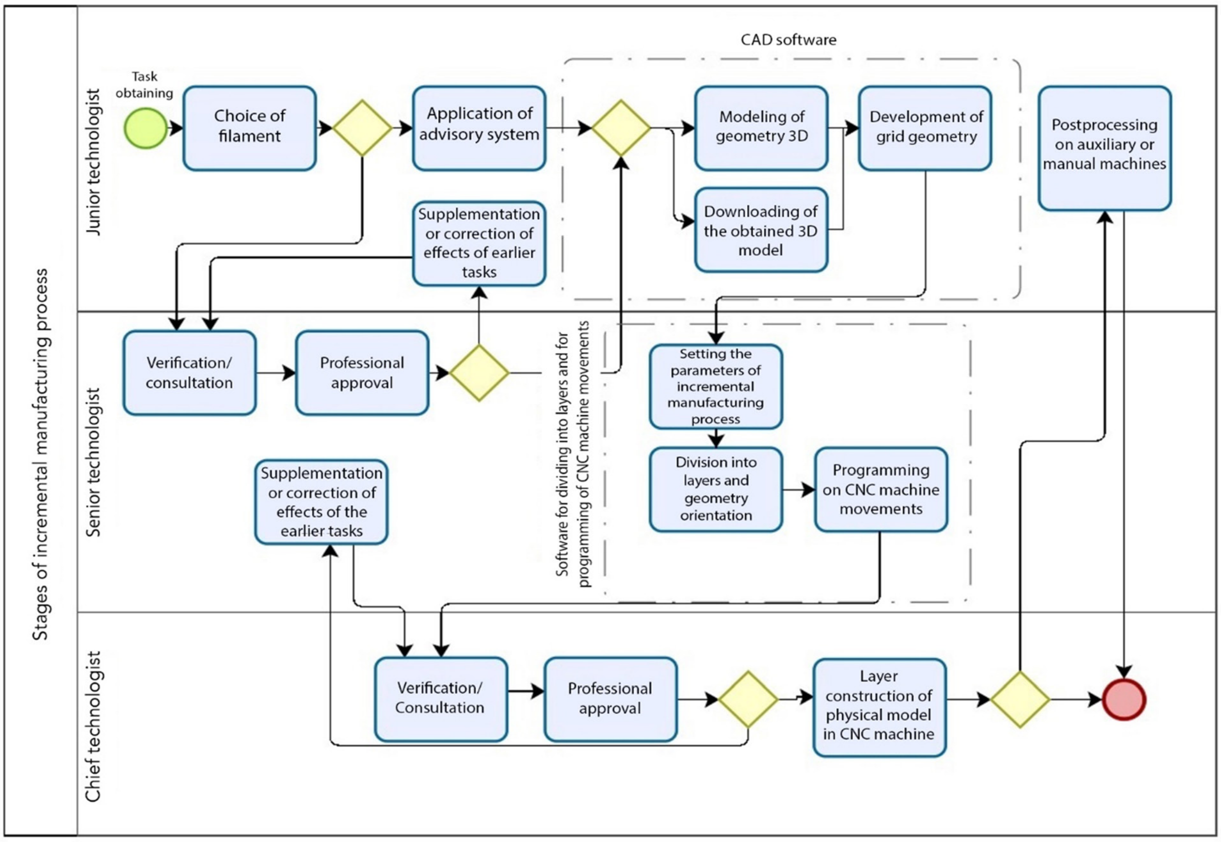

Fig. 5. The stages of the incremental manufacturing process in conceptional aspect at the technological department of the enterprise, with the consideration of advisory system application (own development)

In the mentioned above process, the choice of filament is a significant element, affecting the quality and yield of the printed product. The incorrect choice of filament may lead to defects and errors in print, what increases the time of the order implementation and the manufacturing costs.

Based upon the simulation data, we may state that the duration time of the stages of incremental manufacturing process may be by 10% abbreviated in the case of employment of advisory system. It means that the time of performing the particular stage of the process may be by 10% decreased as compared to the times obtained in the case of lack of advisory system application. The exemplified simulation model, as implemented in Flexsim software, based on the mentioned above stage of incremental manufacturing in conceptional aspect at technological department of the enterprise, with the consideration of advisory system has been illustrated below (Fig. 6). The simulation which was carried out, concerned also two variants as in the case of the previous process. Variant I assumed the run of the process with the application of the advisory system and considered the complete passage via areas A, C, D and E, represented in the scheme given below (Fig. 7).

On the other hand, variant II assumes the run of process without the application of advisory system. The simulation run of the mentioned variant is implemented partially via area A until the moment of reaching the height of decision area 1; then, the order passes through the processes in areas B, C, D and E. In area A, the simulation process is commenced and at the same time, it is a segment where the choice of filament and advisory system are found, there is also here a decision

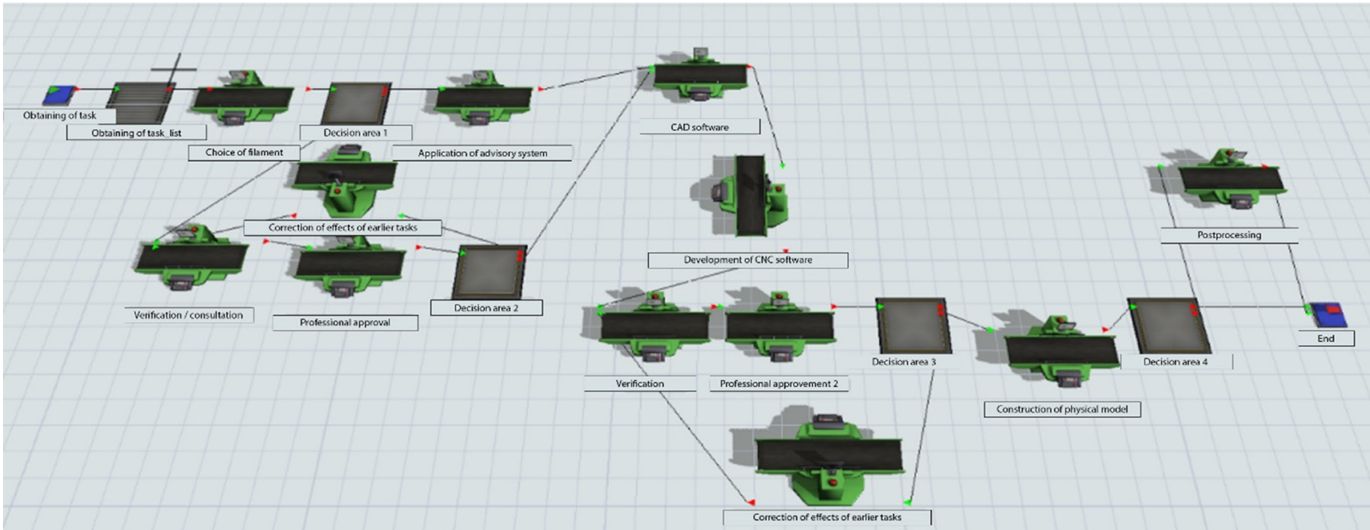

Fig. 6. Example of a simulation model in the FlexSim environment for the additive manufacturing process (screenshot developed in collaboration with Mr. Mateusz Gacek)

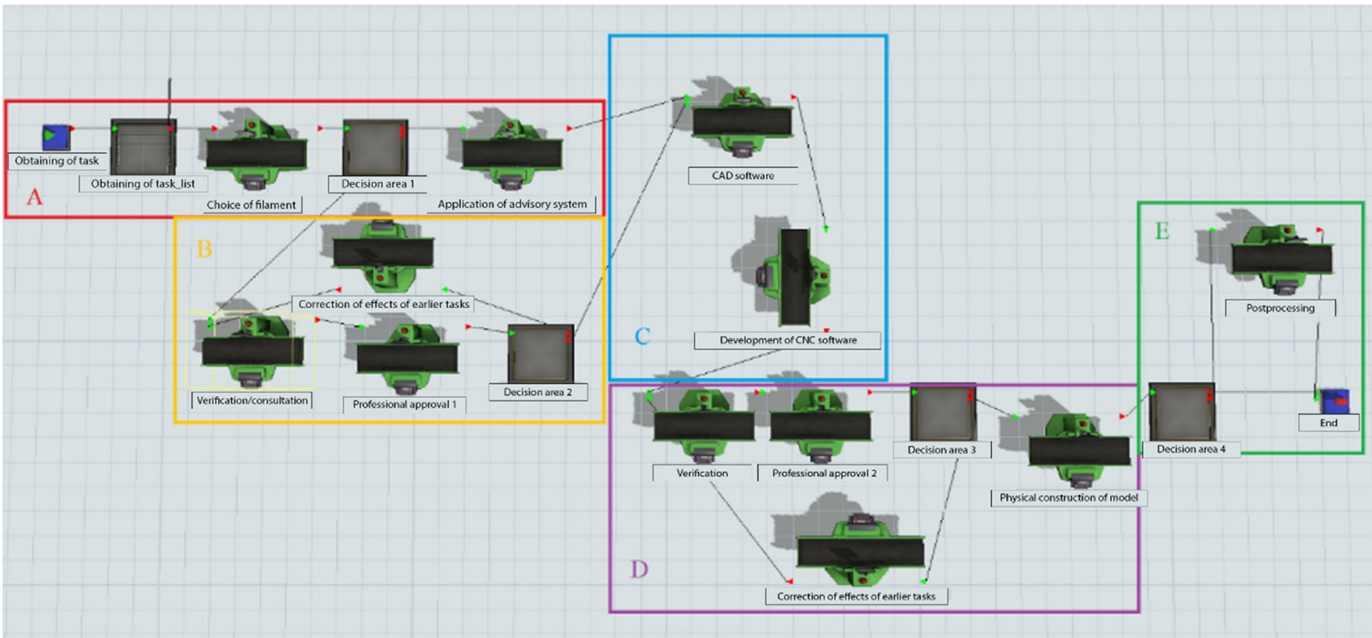

Fig. 7. Simulation areas using Flexsim software (screenshot developed in cooperation with Mr. Mateusz Gacek)

area that re-directs the process to area B. Area B assumes verification of the suggested solution by more experienced technologist. The decision area assumes that the probability of occurrence of the need of correcting the operations or postprocessing is equal to 0.1. Analogically, the probability of non-occurrence of any complications is 0.9. The presence of the decision area in the discussed region creates the possibility of the process looping, that is, the requirement of correcting the operations – the repetitions of the processes which prolong the total time of the implementation of the order. After performing all necessary actions, the order is addressed to area C. For the needs of simulation, the area C has been simplified to two processes. In areas D and E, the prolongation of the time of order implementation may occur due to detection of irregularities and repetition of the loop.

Table 4. Simulation times [h] for incremental manufacturing process in variant without the application of advisory system

Process	Average process time	Minimum process time	Maximum process time
Choice of filament	0,33	0,29	0,37
Application of advisory system	0,00	0,00	0,00
CAD software	6,15	3,46	12,53
Development of CNC software	10,92	10,01	15,35
Correction of effects of earlier tasks	0,00	0,00	0,00
Verification – consultation	3,36	0,97	7,72
Professional approval	0,25	0,23	0,27
Verification	0,27	0,25	0,39
Professional approval 2	0,50	0,50	0,50
Correction of effects of earlier tasks	3,68	3,01	4,37
Construction of physical model	10,43	10,00	12,36
Postprocessing	1,00	1,00	1,00

Table 5. Total simulation time for the incremental manufacturing process in variant without application of advisory system

Total time		
Average process time	**Minimum process time**	**Maximum process time**
32,69	28,24	39,17

Table 6. Simulation times [h] for incremental manufacturing process in variant with the application of advisory system

Process	Average process time	Minimum process time	Maximum process time
Choice of filament	0,33	0,28	0,37
Application of advisory system	0,17	0,17	0,17
CAD software	6,03	3,45	10,24
Development of CNC software	10,92	10,01	13,62
Correction of effects of earlier tasks	0,00	0,00	0,00
Verification – consultation	0,00	0,00	0,00
Professional approval	0,00	0,00	0,00
Verification	0,28	0,25	0,48
Professional approval 2	0,50	0,50	0,50
Correction of effects of earlier tasks	3,75	3,22	4,29
Construction of physical model	10,42	10,00	11,98
Postprocessing	1,00	1,00	1,00

Table 7. Total simulation time for incremental manufacturing process in variant with the application of advisory system

Total time		
Average process time	**Minimum process time**	**Maximum process time**
29,34	25,86	36,01

Table 8. Presentation of the extrapolated summarized times for 100 iterations and the average times for the both variants (own development)

	Variant I: Application of advisory system	**Variant II: Lack of the application of advisory system**
Mean time	29.34 [h]	32.69 [h]
Extrapolated summarized time for 100 iterations	2934 [h]	3269 [h]

The times for the processes have been differentiated using a normal or Pareto distribution. Values given in Tables 4, 5, 6 and 7 mean the assumed time in hours for the both variants of simulation. The total time of the process run means the time, measured from the task obtaining until the end. The times of the individual processes, i.e. their average, minimum and maximum times were also examined.

In Tab. 8 (below) the times of the processes for the both variants were submitted in a graphical form; they were obtained using the simulation of the process repeated 100 times in each configuration. The diagrams show the average times of the both variants and the extrapolated summarized times for 100 processes. Such procedure allows the evaluation of the process' effectiveness for 100 iterations. In the discussed case, the time was abbreviated by 335 hours for 100 orders.

Summing up

The performed research work provided new knowledge on the actual values of strength parameters of PET thermoplastic formed in the FFF process. In the light of the achievements published in the literature so far, the analysis conducted constitutes a separate approach to a specific problem. The results in question supplement the previous material data in the area of the influence of changes in the printing process parameters on the selected mechanical properties of thermoplastic material commonly used in additive manufacturing techniques. It should be emphasized that the research work carried out constitutes a representative fragment of the study, which fully takes into account additional different model settings in the workspace of the manufacturing equipment. The results determined in the static uniaxial tensile test and static torsion test indicate higher strength values for the research sample models printed using a layer thickness of 0.2 mm. For the maximum tensile stress, the difference is over 23%, and for the tensile strain less than 10%. Similarly, higher torsional strength was determined for the samples with a layer thickness of 0.2 mm. The maximum torsion torque is higher in the variant in question by almost 30% than the maximum torsion torque determined for the 0.3 mm variant. On the other hand, the angle of torsion at sample fracture was determined at a level almost 70% higher for the 0.2 mm variant.

Of course, in the case of the target application of models in a load system requiring lower strength, it is advisable to print in the 0.3 mm layer thickness variant due to the economic factor. The printing time of the series of research models with a defined layer thickness of 0.3 mm was by 20% shorter than for the 0.2 mm variant. The level of material consumption was determined at a similar level for both variants.

The determined strength test results can be used in the process of determining the application area of additively manufactured parts using the FFF technique from thermoplastic PET material. Additionally, in the test process, the values of torsional strength parameters were determined, which are not provided by the manufacturers of model materials, but are necessary for parts such as machine shafts, clutches, gear hubs and many others loaded with torsion torque.

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MATHEMATICAL ANALYSIS OF MECHANICAL AND THERMAL PROPERTIES OF HEMP SHIVE-BASED COMPOSITES – REGRESSION MODEL FITTING

ANALIZA MATEMATYCZNA WŁAŚCIWOŚCI MECHANICZNYCH I TERMICZNYCH KOMPOZYTÓW NA BAZIE PAŹDZIERZY KONOPNYCH – DOPASOWANIE MODELU REGRESJI

***Summary**: This study investigates the dependencies between mechanical and thermal characteristics of hemp shive-based composite. The composites of this type are becoming popular because they are environmentally friendly, provide good thermal insulation, and have strong mechanical properties, serving as a viable alternative to traditional building materials. The research analyzes how these materials conduct heat and withstand pressure, using different ratios of hemp shive to binder. To predict the behavior of the mentioned materials, three mathematical models were applied: linear, quadratic, and exponential. The study has determined that linear models are the most effective for practical applications, as they have high R^2 values, indicating a good fit with the data. A strong correlation was found between thermal conductivity and compressive strength, which helps in improving composite designs. The results endorse the use of hemp-based composites in construction, highlighting their ability to balance thermal efficiency, mechanical strength, and environmental sustainability. The study suggests more research to explore alternative binders, assess long-term durability, and evaluate the feasibility of large-scale production.*

***Keywords**: hemp composite, mathematical modeling, regression modeling, sustainable construction*

Streszczenie: W pracy zbadano zależności pomiędzy właściwościami mechanicznymi i termicznymi kompozytu na bazie paździerzy konopnych. Kompozyty tego typu cieszą się coraz większą popularnością, ponieważ są przyjazne dla środowiska, zapewniają dobrą izolację termiczną i posiadają dobre właściwości mechaniczne, stanowiąc realną alternatywę dla tradycyjnych materiałów budowlanych. W badaniu analizowano, w jaki sposób te materiały przewodzą ciepło i wytrzymują ciśnienie, stosując różne proporcje paździerzy konopnych do spoiwa. Do przewidywania zachowania tych materiałów zastosowano trzy modele matematyczne: liniowy, kwadratowy i wykładniczy. W badaniu ustalono, że modele liniowe są najskuteczniejsze w zastosowaniach praktycznych, ponieważ mają wysokie wartości R^2, co wskazuje na dobre dopasowanie do danych. Stwierdzono silną korelację między przewodnością cieplną a wytrzymałością na ściskanie, co pomaga w ulepszaniu projektów kompozytów. Wyniki potwierdzają zastosowanie kompozytów na bazie konopi w budownictwie, podkreślając ich zdolność do równoważenia wydajności cieplnej, wytrzymałości mechanicznej i zrównoważenia środowiskowego. Badanie sugeruje dalsze badania w celu zbadania alternatywnych spoiw, oceny długoterminowej trwałości i oceny wykonalności produkcji na dużą skalę.

Słowa kluczowe: kompozyt konopny, modelowanie matematyczne, modelowanie regresyjne, budownictwo zrównoważone

Introduction

Growing concerns about environmental impacts and increases in building performance have shifted construction industry interests toward sustainable materials [1, 2]. Hemp composites, and specifically those based on hemp shives (the woody core of the hemp plant), have attracted attention because of their good mechanical and thermal properties [3, 4, 5]. Ecofriendly material replacements that are renewable can be a substitute of the traditional construction elements which would correspond to the global sustainable development views and objectives [6].

Hemp shives have a high porosity, which results in good thermal insulation characteristics. The thermal conductivity of materials based on hemp shive is found to vary between 0.090–0.160 W/(m·K), with a slight increase in value occurring with increasing material density [7]. The intrinsic porosity not only improves thermal insulation by counteracting heat transfer but also causes sound installation characteristics [8].

Hemp composites exhibit good mechanical properties which are impacted by the size of the shives and the binder used. The previous studies indicated that composites based on fine shives resulted in a higher mechanical strength than composites based on coarser shives [7, 9, 10]. Also, the setting and properties of the material largely depend on the binding–matrix relationship, which occurs in the binder and hemp particles [11, 12]. Example: An air lime-based binder has also been linked with enhanced mechanical properties of hempcrete [1, 8, 11].

Apart from mechanical and thermal properties, hemp composites are showing interesting hygrothermal properties [13, 14, 15]. The material is a way of moisture regulation, which plays a role in indoor air quality and occupant satisfaction [16, 17, 18, 19, 20]. Because of this feature, as well as its thermal performance, hemp-based composites are used in energy-efficient building solutions [4, 21].

Then again, the composite materials could be famous at the integration of hemp shives which ensures sustainability of building [22]. This relation is essential as it can bridge together the physical properties of hemp shives, the selection of binders, and the processing parameters to formulate sustainable materials with high mechanical and thermal performance.

Understanding the interplay between mechanical and thermal properties is crucial in materials engineering, as it influences the performance and reliability of materials under various operational conditions [3]. Mechanical properties, such as strength, elasticity, and toughness, dictate a material's ability to withstand forces without deformation or failure. Thermal properties, including thermal conductivity, determine how a material responds to temperature changes, affecting its ability to conduct heat or store thermal energy [6]. For designers, mathematical dependencies between the amounts of raw materials included in the composite and its physical properties are important. These relationships allow the composition of the composite to be formulated in relation to the mechanical (e.g. compressive strength) and thermal requirements (e.g. thermal conductivity coefficient). Moreover, the mathematic relationship can be found between the compressive strength and thermal conductivity coefficient. This relationship is useful for designing the hemp – binder composition with taking into account not only the physical parameters of the composite but also the prices of its components and its total carbon footprint. Such composite carbon footprint is negative according to [23, 24] due to hemp shives' content. The relationship is as follows: the more hemp shives, the greater the negative carbon footprint of the composite. However, mechanical and thermal properties of the composite are changing due hemp shives content. The construction material should meet durability requirements. The aim of the present work is to analyze the mathematical relationships between mechanical and thermal parameters according to the proportions of hemp shives and lime binder.

Materials and methods

Brzyski [25] investigated different properties of hemp composite consisting of hemp shives and lime binder in different proportions and with different materials grouped in series. The results of Series 1 where lime binder was modified by addition of 15% concrete type CEM II/B-V 32,5R and 15% metakaolinite are specially interesting for the analysis. Table 1 presents the component content.

Table 1. Components' content

Component	S1.1	S1.2	S1.3	S1.4
Water (kg/m³)	394.1	373.0	351.9	330.8
Hemp shives K1 (kg/m³)	140.8	140.8	140.8	140.8
Metakaolin (kg/m³)	42.2	38.6	35.3	31.7
Cement CEM II/B-V 32.5R (kg/m³)	42.2	38.6	35.3	31.7
Hydrated lime (kg/m³)	197.1	180.3	164.5	147.8

Source: Brzyski [25]

Table 2. The thermal conductivity coefficient according to weight proportions of hemp shives: binder

Weight proportions of hemp shives: binder	Thermal conductivity coefficient (W/m K)		
	Minimum	Average	Maximum
1:2	0.1190	0.1220	0.1250
1:1.83	0,1090	0.1130	0.1170
1:1.67	0.0975	0.1010	0.1045
1:1.5	0.0848	0.0880	0.0912

Source: own elaboration based on Brzyski [25]

Table 3. The compressive strength according to weight proportions of hemp shives: binder

Weight proportions of hemp shives: binder	Compressive strength (MPa)		
	Minimum	Average	Maximum
1:2	0.305	0.32	0.335
1:1.83	0.272	0.29	0.308
1:1.67	0.243	0.26	0.277
1:1.5	0.214	0.23	0.246

Source: own elaboration based on Brzyski [25]

Table 2 presents the thermal conductivity coefficient according to weight proportions of hemp shives: binder. Table 3 presents the compressive strength according to weight proportions of hemp shives: binder.

There will be fitted to data the following mathematical models: linear, quadratic and exponential. Also, a linear model will be fitted to determine the dependence between the thermal conductivity coefficient and compressive strength.

Results

Table 4 presents fitting results. All models show very high coefficients of determination. However, the linear models could be the best in practical use.

Table 2. The thermal conductivity coefficient according to weight proportions of hemp shives: binder

Model	Thermal conductivity coefficient (hemp shives)
Linear, R^2	$y=0.0679 \cdot x-0.0147$, $R^2=0.9696$
Quadratic, R^2	$y=-0.0416 \cdot x^2 +0.2119 \cdot x-0.1380$, $R^2=0.9786$
Exponential, R^2	$y=0.0319 \cdot \exp(0.6721 \cdot x)$, $R^2=0.9562$
Model	**Compressive strength (hemp shives)**
Linear, R^2	$y=-0.0412+0.1807 \cdot x$, $R^2=0.9999$
Quadratic, R^2	$y=-0.0412+0.1807 \cdot x+0.0000 \cdot x^2$, $R^2=0.9999$
Exponential, R^2	$y=0.0856 \cdot \exp(0.6625 \cdot x)$, $R^2=0.9973$
Model	**Thermal conductivity coefficient (Compressive strength)**
Linear, R^2	$y=14.2736 \cdot x+0.2618$, $R^2=0.9696$

Source: own elaboration

Summing up

The study highlights a growing interest in eco-friendly building materials like hemp composites. Hemp shives, small particles of hemp, provide a low thermal conductivity and strong mechanical strength, making them a viable alternative to traditional building materials. Additionally, they offer environmental benefits with a negative carbon footprint.

The study employs various mathematical models — linear, quadratic, and exponential — to accurately predict the thermal conductivity and compressive strength of these materials. These models are reliable in forecasting material properties.

A strong correlation was identified between thermal insulation and compressive strength using a linear model, aiding in the design of materials that effectively balance heat retention and structural strength.

Guidelines for developing hemp-lime composites are provided, focusing on mechanical and thermal performance. Mathematical predictions assist engineers in selecting materials by weighing factors like cost-effectiveness and sustainability.

Future research could investigate:

- The impact of different binders and additives on performance.
- The long-term durability and moisture resistance of hemp-based materials.
- Methods to scale up production while preserving sustainability benefits.

The study confirms that hemp composites are a sustainable choice for construction, offering a balance of thermal efficiency, mechanical strength, and low environmental impact.

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CLASSIFICATION OF FEED USED IN DUCK NUTRITION

PODZIAŁ PASZ STOSOWANYCH W ŻYWIENIU KACZEK RZEŹNYCH

***Summary**: Ducks belong to a group of omnivorous birds. In comparison to gallinaceous birds such as hens or turkeys, they are characterized by a greater voracity and smaller feed preference. They are also distinguished by a higher resistance to unfavorable environmental conditions and lower feed quality. The characteristic feature of duck is well-developed microbiota of blind guts (caecum) that enables the effective utilization of vegetal feed. At the same time, the construction of their alimentary tract does not allow to employ the feed mixtures destined for hens and turkeys in their nutrition.*
The system of duck utilization is the key element determining the way of their nutrition. In the intensive management system, the full-ration mixtures are the basic component of diet whereas in the semi-intensive and extensive systems, the main nutrition basis consists of farm feeds, enriched with feed concentrates.

***Keywords**: duck nutrition, cereals, feed oils, protein feed*

Streszczenie: Kaczki należą do grupy ptaków wszystkożernych. W porównaniu z drobiem grzebiącym, takim jak kury czy indyki, cechują się większą żarłocznością oraz mniejszą wybrednością pokarmową. Wyróżniają się również wyższą odpornością na niekorzystne warunki środowiskowe oraz niższą jakość paszy. Charakterystyczną cechą kaczek jest dobrze rozwinięta mikrobiota jelit ślepych, która umożliwia efektywne wykorzystanie pasz roślinnych. Jednocześnie budowa ich układu pokarmowego uniemożliwia stosowanie w żywieniu mieszanek paszowych przeznaczonych dla kur i indyków.

Kluczowym czynnikiem determinującym sposób żywienia kaczek jest system ich użytkowania. W intensywnym systemie chowu podstawowym składnikiem diety są mieszanki pełnoporcjowe, natomiast w systemach półintensywnym i ekstensywnym główną bazę żywieniową stanowią pasze gospodarskie wzbogacane koncentratami paszowymi.

Słowa kluczowe: żywienie kaczek, zboża, oleje paszowe, pasze białkowe

Introduction

The main aim of meat-type ducks nutrition is to obtain the birds with a correct body conformation, with the preservation of optimum fattening level, musculature and good quality feathering. The duck broilers should have the ensured access to *ad libitum* feed during the whole rearing period. Due to the fact that the costs of nutrition constitute up to 68% of total production costs, the appropriate diet balancing plays a crucial role in the effectiveness of rearing. A short production cycle requires a precise choice of feed components in order to prevent the deficits, which may have a negative impact on a final effect of fattening [29].

The purpose of the present work is to submit the principles of duck nutrition, with the consideration of their unique feeding requirements and the in-the-market available raw feed components.

Cereals and feed oils

The concentrates with a high energetic value should constitute ca. 70% of feed ration for the ducks. Their basis includes the cheapest feed components, first of all, cereal grains. In Poland, corn, wheat and barley are used most frequently and oats is applied more rarely. Millet may be an alternative to the traditional cereals and in production of the feed mixtures for duck broilers, the additives of sorgo, triticale and rye are also allowed. Their presence requires, however, the constant monitoring. Apart from the cereals, fodder oils, brans and oily plant seeds are also used in duck nutrition.

Production and utilization of feeds by meat-type ducks

The intensive fattening of the meat-type ducks lasts usually for 7 weeks [8, 23]. During the mentioned period the birds obtain body weight in the range of 2300–3100 g, according to the gender. Dressing percentage of the ducks is estimated at the level of 65–70% [8]. Body weight gains of Pekin ducks are similar as the discussed values obtained for broiler chickens and may amount to 45 g per each 100 g of the consumed feed [2].

During the first week of life, one day-old chicks consume about 350 g of feed, the composition of which not always covers their requirements of energy and protein [2]. The improper supplementation of the diet during the discussed period may lead to the nutritional deficits, resulting in production losses in the successive stages of rearing.

Energetic raw feed materials employed in production of mixtures for the meat-type ducks

Concentrates are the basic component used in duck nutrition. Their participation in feed mixtures is equal to 60–80%. The discussed group includes:

- Cereals (50–80% of the feed mixture) (Table 2);
- Products coming from cereals' processing (e.g. brans, fodder meals);
- Seeds of oily plants;
- Feed oils (5–10% of the feed mixture).

Table 1. The examples of the formulations of feed mixtures type starter and grower for duck broilers [2]

Feed component	Type of feed	
	starter	grower
Corn	57%	73.4%
Extraction soy meal (protein content at the level of 48%)	36%	20.5%
Soy oil	3%	2.5%
Feed calcium carbonate ($CaCo_3$)	1.6%	1.4%
Calcium phosphate ($Ca_3(Po_4)_2$)	1.4%	1.2%
Animal feed salt (NaCl)	0.4%	0.4%
Mineral-vitamin premix	0.3%	0.3%
Methionine	0.3%	0.2%
Lysine	-	0.1%

Table 2. The contents of nutritional components in kg of different cereals and brans according to the National Research Institute of Animal Production – Balice (2010)

Raw material	Nutrients				
	Total protein	Crude fat	Crude fiber	Nitrogen-free extractives	Crude ash
	%				
Corn (grain)	10.2	4.7	2.6	80.6	1.9
Wheat (grain)	13.7	1.9	3.5	78.9	2.0
Wheat (brans)	16.6	3.9	9.0	65.7	4.8
Barley (grain)	12.6	2.1	5.3	77.3	2.7
Naked barley (grain)	13.1	2.4	1.5	80.6	2.4
Barley (brans)	14.0	4.6	12.6	64.2	4.6
Oats (grain)	12.3	4.1	12.7	68.0	2.9
Triticale (grain)	13.0	1.6	2.9	80.5	2.0
Rye (grain)	10.3	1.7	2.3	83.8	1.9
Rye (brans)	15.5	2.9	5.3	72.2	4.1

The cereals being most often used in the feed mixture are corn, wheat, barley and oats, and, also, millet, sorgo, triticale and rye. Additionally, the seeds of oily plants and feed fats are employed.

Nutritional suitability of the particular energetic raw materials:

- **Corn** – corn (maize) is distinguished by the highest energetic value from among all cereals; at the same time it is characterized by one of the lowest crude fiber content. The content of starch in corn grain is equal to 68%–74% whereas that of crude fat is 4%–5.5 % of grain weight [35]. Lipid content of corn includes oleic acid (19.5 – 30.5%), linoleic acid 953 – 65.3%) and palmitic acid (9.2–12.1%) and also, ß-carotene and other carotenoids, including zeaxanthin, kryptoxanthin and lutein [14]. Digestibility of corn is estimated at the level of 85%. As compared to other cereals, corn contains less protein which is characterized by a lower biological value. It is mainly composed of glutelin and zein and is poor in exogenous aminoacids such as lysine and tryptophan which play a crucial role in animal nutrition. Owing to high digestibility and lack of antinutritive compounds, corn meal may be used as feed component in the mixtures intended for all production groups of the ducks. It is important to remember to keep a constant check on the raw material being sourced, as maize purchased or used in the production of finished feed may be infected with mycotoxins – the secondary metabolites of fungi which are developing in the conditions of the increased humidity e.g. in the case of the insufficient drying of the grain or its storage in the warehouses with the improper microclimate conditions (high humidity and air temperature) [4, 17, 18]. The main mycotoxins occurring in corn are fumonisin B1 [41] and aflatoxin B1 [17, 18]. Aflatoxins in feeds may lead to the decrease of the body weight gains, permanent damage of liver of the ducks and, also, to the increase mortality in the flock. To limit partially a negative impact of the mentioned toxins, it is recommended to increase the supplementation of selenium and vitamin E [17, 18]. In order to limit a harmful effect of mycotoxins in feeds, the detoxicants such as active carbon and active aluminosilicates are employed; the mentioned compounds reveal the capability of adsorbing the mycotoxins, restricting their negative impact on the animal organism.
- **Wheat** is a cereal, the cultivation area of which in Poland is constantly increasing. When cultivating the wheat on the more fertile soil of I – III class , we may obtain even 80–100 dt of yield from 1 ha for winter wheat [31] and 50–70 dt/ha for spring wheat [37]. The yield of wheat grain is found on the second place, directly after corn which gives the performance equal to 100–125 dt/ha [34]. A high energy concentration together with the considerable level of total protein and a low content of crude fiber make that the wheat is characterized by a high feeding suitability. In combination with the high yielding, it causes that it is one of the major feed components in the mixtures for poultry. The studies of Kokoszyński et al (2017) [23] revealed that the replacement of 15% commercial mixture by wheat in fattening of Pekin ducks did not affect negatively production parameters (final weight, dressing percentage, feed conversion ratio (FCR). Introduction of the full wheat grain to the diet of poultry may favorably affect the functioning of alimentary tract, mainly due to the lower passage of the intestinal contents. Moreover, the full wheat grain causes the increase of muscular and glandular stomach what improves the excretion of enzymes and intestinal peristalsis.
- **Barley** is one of the main feed cereals cultivated in Europe, with the average yielding at the level of 51dt/ha–75dt/ha [37]. Similarly as oats, it is classified as hulled cereal what results in higher content of crude fiber in the grain, lowering the feeding value of the raw material. Nevertheless, barley is characterized by a smaller amount of hulls as compared to oats. On the market, there are also available "naked" varieties of barley and oats, deprived of hulls but their application is limited due to higher production costs. In duck nutrition, a high level of antinutritive substances in the grain of barley is a challenge; it refers especially to non-starch polysaccharides (NSP) such as arabinose, xylose, fucose, mannose, and glucans. Although the ducks digest barley starch effectively at the level of ca. 99%, their capability to digest NSP is considerably lower, amounting only to ca. 20% [20]. The presence of NSP in the diet may lead to increase of the viscosity of intestinal contents, what has a negative impact on digestion and absorption of nutrients. In order to minimize the mentioned unfavorable defects, it is recommended to employ enzymatic additives such as xylanases and ß-glucanases, which decompose NSP, improving the digestibility of nutrients and total feeding effectiveness of ducks. Introduction of enzymes to feeds for poultry is a common practice, aiming at the increase of the availability of nutrients and improvement of production parameters. The studies indicate that the addition of the enzymes of bacterial origin may effectively reduce the negative effects of the soluble NSP activity in alimentary tract of young chicken broilers what suggests similar effects in the nutrition of ducks[19]. Moreover, the appropriately balancing of diet and observing the recommendations concerning the participation of the particular cereals in the feed mixtures are crucial for optimization of production results and health state of the ducks [19].
- **Oats** is characterized by the highest content of crude fiber, exceeding 10% what limits its energy value. The protein content in the oats is equal to ca. 11%. In spite of the mentioned above properties, oats could be a valuable component in the feed mixtures for the ducks. However, due to a relatively low yielding, amounting to 41 dt/ha–70 dt/ha [37], its application in the greater scale is limited. Introduction of oats to the diet of the ducks may bring the profits such as the supply of indispensable aminoacids and improvement of intestinal peristalsis owing to a high fiber content. Due to a lower energy content and higher level of fiber, it is however recommended to use oats in combination with other cereals such as wheat or corn (maize) in order to ensure the correct balance of nutrients. It is important to monitor the quality of oats as to avoid the presence of antinutritive substances which may affect negatively the health and performance of the ducks.
- Triticale is a cereal which is characterized by the most variable content of total protein from among all cereals (9–16%). Protein

concentration in triticale is dependent on the soil [13] and climate conditions [10]. The digestibility of triticale is similar as that of wheat.

- **Rye** – unfortunately, the grain of the mentioned cereal is not readily consumed by the birds and is characterized by a relatively low digestibility. It contains antinutritive substances from the non-starch polysaccharides group, and in particular, pentosanes (arabinoxylans) which are harmful to the poultry. The content of pentosanes in the rye grain is estimated at ca. 10% [7]. The application of rye in the feed mixture requires a constant control because the excessive amount of the discussed cereal may lead to impairment of the growing processes of the birds. Due to the presence of the antinutritive substances, rye should not be combined with triticale or other cereals which may contain the similar substances.
- **Millet** is a cereal with a high tolerance to water deficits what makes it especially popular in the regions suffering from deserts and draughts, mainly in Africa and Asia. In the nutrition of ducks, millet may be an alternative to corn. The studies revealed that the complete replacement of corn by the millet did not have any negative influence on the body gains, feed intake or feed conversion coefficient of the ducks [2].
- **Feed oils** are utilized with the aim to balance correctly the energy in the feed mixtures for the poultry. Additionally, feed fats play a role of solvents and vectors for vitamins A, D3, E and K and, also, reduce the dustability of the feed. It was revealed that the 4%-addition of rape, soy, palmitic or coconut oils did not cause any differences in the body weight gains of the young ducks [15].

Protein feeds

Protein feeds are the key element in the duck nutrition as they have a direct impact on their growth, development and production profitability. The main source of protein in the feed mixtures for poultry are protein concentrates the nutritional value of which is greatly dependent on the quality of the discussed component. The quality of the protein feeds used in the ducks' nutrition is dependent on the content of antinutritive substances, crude fiber, composition of aminoacids and digestibility and assimilability of protein. Protein is one of the feed components which has a direct effect on production profitability.

In the nutrition of ducks, protein feeds deriving from different sources, are applied. By-products of oil industry such as extraction meals, oil cakes and expellers have the most important economic meaning. The extraction meals are especially valuable in the traditional systems of poultry management; however, in the organic system, their application is not allowed. In feed industry, there are also utilized the by-products of starch industry such as cereal gluten and cereal and potato protein; it also includes brewery by-products such as e.g. dried distillers with solubles (DDGS). Distilled by-products such as dried distiller's grains and brewery yeasts find also application in the feeds intended for ducks.

The by-products of the dairy industry such as dried whey or milk powder are expensive feeds of animal origin, the utilization of which is limited due to the presence of lactose. Since August 2021, it has been possible to employ insect powder and meat-bone meals in the poultry nutrition, with the preservation of the principle of cross-feeding. Meals obtained from fish and marine invertebrates have been for the years used in feeding industry. The seeds of legumes are promoted in Poland as a domestic source of protein, but in spite of agricultural payments, their cultivation is not popular.

The examples of the particular raw materials, used in production of protein feeds:

- Seeds of legumes (being once named as *Leguminosae*) are obtained from the plants belonging to *Fabaceae* family. Owing to the symbiosis with the diazotrophic bacteria, the species

Table 3. The contents of chemical components (% dry matter) in the seeds of leguminous plants according to the National Research Institute of Animal Production – Balice (2010)

Raw material	Nutrients				
	Total protein	Crude fat	Crude fiber	Nitrogen-free extractives (sugars)	Crude ash
	%				
Field pea	23.8	1.3	6.5	65.0	3.4
Field bean	29.8	1.3	9.3	55.7	4.0
White lupine	40.3	6.4	16.3	32.4	4.7
Blue lupine	33.8	5.7	14.9	41.1	4.5
Yellow lupine	43.0	5.3	15.1	31.5	5.2
Common vetch	33.9	0.8	4.9	56.7	3.7
Soy	34.6	19.9	7.4	14.2	6.5
Grass pea (*Lathyrus sativus*)	32.2	1.0	6.7	17.7	4.0

of the plants belonging to the mentioned family acquire the capacity to fix nitrogen gas from the atmosphere [1]. A close relation between the roots of *Fabaceae* plants and *Rhizobia* bacteria contributes, *inter alia*, to obtaining better yields with the increased level of total protein in the seeds [22]. The main species of leguminous plants, the seeds of which are used as feed components in production of feed mixtures for the poultry include field pea, field bean, common and winter vetch, yellow, white and blue lupine, soy and grass pea (*Lathyrus sativus*) (Table 3).

The seeds of leguminous seeds contain 23%–43% of total protein which is poor in sulphur aminoacids and tryptophane [33]. From among the mentioned plants, the seeds of yellow lupine have the highest level of protein; it exceeds 43% what causes that they are comparable with extraction soy meal in respect of the protein content. On the other hand, the lowest level of total protein was found in the seeds of field pea.

We should, however, pay attention to the presence of antinutritive substances in the seeds of leguminous plants such as:

- Tannins, saponins, trypsin and chymotrypsin inhibitors [33];
- Lupinins (alkaloids), cyanogenic glycosides, oxalyldiaminopropionic (ODAP) acid [38];
- Phytic acid.

Most of the mentioned substances is thermolabile what means that their activity may be reduced or neutralized during the heat treatment such as extrusion or micronation. The additional methods such as dehulling of the seeds and the appropriate breeding work may also contribute to the reduction of the discussed substances.

Due to a high content of protein and lowered level of antinutritive substances, the processed seeds of the newest varieties of lupines may become – up to 60% – the replacer of extraction soy meals in the feed mixtures for the meat-type ducks [26]. In the nutrition of the meat-type poultry, it is recommended to have the participation of the seeds of the leguminous plants in the feeds at the level of 5% during rearing period and ca. 10% for the older birds [12, 36].

- **Extraction meals** are the by-products of oil industry that are obtained during the extraction of oil from oil cake, with the application of chemical solvents e.g. hexane. The basic property, differentiating the extraction meals and oil cakes and expellers consists in the level of fat (ca. 1–5% for extraction meals (Table 4), ca. 8–10% for the expellers and ca. 10–19% for the cakes). Another meaningful aspect differentiating the extraction meals and oil cakes and the seeds of leguminous plants includes a lowered level or the complete neutralization of antinutritive substances as a result of expanding and extruding processes. In the market, there are available extraction meals, derived from the treatment of the seeds of soy, rape, sunflower, peanuts, Elaeis guineensis (palm seed extraction meal), less often from copra (obtained as a result of extraction of dried white flesh of coconut and external hull of the coconut palm seeds), cotton or alga meal.

Soy extraction meal is one of the most frequently used sources of protein in feeds for monogastric animals what results from its high digestibility and favourable amino acid composition, in particular the content of exogenous aminoacids. Moreover, it is characterized by a lower level of crude fiber and antinutritive substances what makes that it is especially effective in the nutrition of monogastric animals [43]. According to the estimates, production of soy protein satisfies ca. 45% of the world demand on feed protein [30] and in Poland the mentioned value is equal to ca. 62% [21, 45].

The rape extraction meal is the alternative to soy extraction meal; it is characterized by a high content of total protein and sulphuric aminoacids, especially the exogenous ones. In spite of this fact, the complete replacement of the soy extraction meal by the rape meal in the feeds for the young poultry may be difficult due to the higher level of crude fiber in the second discussed product [33]. In turn, the studies conducted by Fazhi et al. (2011) [46] indicate that the meat-type ducks, fed with the mixture, containing fermented rape extraction meal and blood meal reached better production results as compared to the birds fed exclusively the soy extraction meal what may suggest the possibility of the complete

Table 4. Contents of chemical substances (% dry matter) in extraction meals of soy, rape and peanut according to National Research Institute of Animal Production – Balice (2010) of cotton [28] and palm [11]

Type of meal	Chemical components				
	Total protein	Crude fat	Crude fiber	Nitrogen-free extractives (sugars)	Crude ash
	%				
Soy extraction meal	50.6	2.0	5.6	34.4	7.4
Rape extraction meal	37.4	4.1	14.6	36.3	7.6
Sunflower extraction meal	32.3	5.8	16.3	9.1	7.5
Peanut extraction meal	50.8	1.3	16.7	24.7	6.5
Cotton extraction meal	47.3	3.0	12.9	29.4	7.4
Palm extraction meal	18.7	2.8	20.2	53.7	4.6

Table 5. The contents of chemical components (% dry matter) in the rape and sunflower cakes according to National Research Institute of Animal Production – Balice (2010), and in sesame [27], hemp [5] and palm oil cakes [11]

Type of oil cake	Chemical components				
	Total protein	Crude fat	Crude fiber	Nitrogen-free extractives (sugars)	Crude ash
	%				
Rape oil cake	35.5	15.9	11.4	30.7	6.5
Sunflower oil cake	30.2	11.9	22.9	27.5	7.5
Sesame oil cake	44.6	11.3	7.3	24.9	11.9
Hemp oil cake	31.9	11.5	30.3	10.0	7.2
Palm oil cake	18.7	2.8	20.2	53.7	4.6

replacing of soy meal by the rape meal. Nevertheless, as it was indicated by Kowalska et al. (2020) [26], the soy extraction meal may be replaced by the rape extraction meal only in 14% what indicates a limited possibility of the complete exchanging the discussed components in the feeds for the poultry.

- Oilcakes are by-products of oil industry, obtained as a result of mechanical extrusion of raw oily materials. They contain 10–19% of fat (Table 5) what makes that they may become a raw material for production of the extraction meals. As compared to extraction meals or expellers, the higher fat content in the oil cake contributes to the increase of its energy value. In Poland, the oil cakes are produced mainly from rape, linen and sunflower whereas at the international market, there are also available soy, sesame, hemp, palm and coconut cakes.
- Dried distiller's grains with solubles (DDGS) is a by-product of edible or industrial (fuel) ethanol production. Its manufacturing process is commenced from the distillation of wet grains (WDG) to which fraction of corn syrup (CCDS) is added what results in production of wet distillers grains with solubles (WDGS) with the dry matter content equal to 40%. Then, the mentioned product is subjected to drying, reaching a dry form (DDGS) with the dry matter content amounting to 90%. DDGS contains 30–35% of total protein and 8–10% of crude fiber. The studies show that the application of 25% of dried corn grain in feed rations for Pekin ducks allows the reduction of the demand on soy extraction meal by 8% and on wheat by ca. 18% without negative health and production consequences [25].
- Gluten is a protein which consists mainly of glutenin and gliadin, playing a crucial role in regulation of energetic processes during the growth of the young cereal seedling. In feed industry, feed gluten is obtained by the wet cereal grinding in the process of starch production. The total content of protein in feed gluten varies from 70% to 80% and its application in the feeds for duck is usually equal to ca. 8% of the ration [16].
- Animal meals – it is a group of feed by-products of animal origin; they include meat-bone meals, fish meals, the meals obtained from feathers, krill, and insects. Animal meals (excluding krill, insect and fish meals) are manufactured during the management of such by-products as feathers, bones, cartilages and fishbones which after combustion contain total protein in the quantities comparable to soy extraction meal. Until now, only the application of fish, krill and feathers' meals was admitted in the nutrition of ducks. According to the Commission Regulation (EU) 2021/1372 of 17 August 2021, it is allowed to use the farmed insect meals and meat, bone

Table 6. The contents of chemical components (% dry matter) in animal meals: meat-bone, feathers, fish according to National Research Institute of Animal Production – Balice (2010) and insect meal (produced from black soldier fly Hermetia illucens)

Type of oil cake	Chemical components				
	Total protein	Crude fat	Crude fiber	Nitrogen-free extractives (sugars)	Crude ash
	%				
Meat-bone meal	45.1	10.7	-	-	40.7
Feather meal	86.5	8.8	0.4	1.5	2.8
Fish meal	73.5	8.1	2.4	0.2	15.8
Meal from black soldier fly (*H. illucens*)	60.8	14.1	7.5	6.7	10.9

and bone-meat meals in feeds for poultry. The application of meat-bone meals in the feeds is limited to the so-called cross-feeding; it means that the meals produced from the waste coming from pork production may be employed in the feeds for the poultry and the meals produced from the poultry meat production may be used in the feeds for pigs. The insect meals must be produced in conformity with the specified sanitary standards and may derive from such species as black soldier fly (*Hermetia illucens*), the house fly (*Musca domestica*), flour beetle (*Tenebrio molitor*), darkling beetle (*Alphitobius*), house cricket (*Acheta domesticus*), banana cricket (*Grillodes sigillatus*), and Jamaican field cricket, silent cricket (*Grillus assimilis*).

Protein concentrates in nutrition of meat-type ducks should constitute ca. 20–25% of the complete feed mixture. In Poland, soy is the main source of feed protein and, more precisely, soy extraction meal which is most frequently imported from Argentina. It is estimated that the imported soy meal covers ca. 70% of the national requirements for feed protein [9]. Such relationship creates a risk connected with the dependence on the foreign supplies what may affect the food safety. One of the solutions which might help in minimization of the mentioned risk is greater utilization of protein sources for feeds such as meal from yellow lupine, fermented blood meal, mixture with the rape extraction meal and animal meals.

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YEAR 2025 – THE JUBILEE YEAR OF ASSOCIATING OF POLISH ENGINEERS AND TECHNICIANS

ROK 2025 – ROKIEM JUBILEUSZOWYM ZRZESZANIA SIĘ POLSKICH INŻYNIERÓW I TECHNIKÓW

The National Council of FSNT-NOT, debating on 27 January 2025 at the Warsaw House of Engineer NOT, under the guidance of Mr. Janusz Turski (SPP) at the suggestion of the Chief Board of FSNT-NOT has decided about establishing the Year 2025 as the Jubilee Year of Associating of Polish Engineers and Technicians.

The resolution was undertaken by the delegates unanimously. Let us remind that the following anniversaries will be celebrated in 2025: 190 years of Polish Engineering Society; 120 years of Warsaw House of Engineer; 90 years of the Chief Organization of Polish Engineers; the 80th Anniversary of the Chief Engineering Organization (NOT) and the 35th Anniversary of the Federation of Engineering Organizations NOT.

The anniversary ceremonies have been established for the engineering associations – the members of FSNT-NOT and other entities, acting within the structures of the Federation. They will be commenced by the ceremonies of the 190th anniversary of Polish Engineering Society which will be held on 14–15.05.2025 in Tarnów.

The National Board decided also to convene the XXVIIIth Congress of Polish Technicians on 8–11.06.2025 in Poznań. The mentioned Congress will be linked with the VIth World Convention of Polish Engineers. The invitation to participate in the organization of the mentioned event will be sent to the representations of various engineering environments being not associated in FSNT-NOT such as the Conference of the Rectors of Polish Technical Universities, The Main Council of the Research Institutes, Engineering Academy in Poland, Polish Academy of Sciences, Poznań University of Technology, European Federation of Polish Engineering Associations and the Council of Polish Engineers in the North America.

The aim of the Congress and the Convention which will be held under the motto:" Engineering for Health and Safety" is to strengthen the role of creative engineering environments and to integrate them as well as to determine the directions for the development of engineering domains having the impact on the improvement of the state of the environment of our Planet.

Source: https://not.org.p./aktualnosci/ dated 28.01.2025

MARCH 4TH WORLD ENGINEER'S DAY

4 MARCA ŚWIATOWY DZIEŃ INŻYNIERA

It was the sixth time when the engineering environment celebrated the World Engineer's Day for the Sustainable Development. The day which has been established by the World Federation of Engineering Organizations (WFEO) and is celebrated under the UNESCO patronage.

This year's celebration of the Day was held under the motto: "Engineering in the Struggle with Poverty". The ceremonies were covered with the Honorary Patronage of Mr. Szymon Hołownia, the Marshall of the Seym (Polish Parliament) and Mr. Marcin Kulasek, the Minister of Science and Higher Education.

The organizers were FSNT-NOT, Łódź University of Technology and the Conference of Rectors of Polish Technical Universities (KRPUT).

The ceremony was opened and the guests were welcomed by the host of the site, His Magnificence Prof. dr. hab. Krzysztof Jóźwik, Eng., the Rector of Łódź University of Technology and the Chairman of KRPUT. The event was participated by many rectors of technical universities and of other higher education schools as well as by the scientific and didactic workers from the higher education schools and research institutes, economic activists, the representatives of business and engineering associations, being associated not only in NOT.

Madame Ewa Mańkiewicz-Cudny, the President of FSNT-NOT has informed about the aim and idea of the meeting as well as about the Year 2025 which is the Jubilee Year of Associating of Polish Engineers and Technicians; she has also stressed that the event has also a special meaning for NOT.

Then, Prof. dr. hab. Marek Gzik, Eng., the Secretary of the State at the Ministry of Science and Higher Education conveyed the best greetings to the present guests and to all Polish engineers. He passed on also the information on the activities, being currently undertaken at the Ministry.

The gratulations and occasional addresses to the participants and organizers of the event were directed by many persons. The first address, directed by Mrs. Małgorzata Kidawa-Błońska, the Marshall of the Senate of Republic of Poland was conveyed by the Senator of RP, Mr. Krzysztof Kwiatkowski. The letter from Mr. Szymon Hołownia, the Marshall of the Seym (Polish Parliament) was read out by Mr. Marcin Strumiłło, Director of the Regional Parliament of Łódź Voivodeship.

Gratulation letters were also sent from Krzysztof Gawkowski, Vice-Premier, the Minister of Digitization, from Paulina Henning-Kloska, the Minister of Climate and Environment, Ewa Zielińska, The President of Polish Committee for Standardization, Prof. Krzysztof Szamałek, Director of the National Institute of Geology, Tomasz Zjawiony, the Vice-President of the National Economic Chamber and from Tadeusz Donocik, the Honorary President of the Regional Economic Chamber in Katowice.

It is difficult to imagine the celebration of the Engineer's Day without the official professional part. The first presentation: "New technologies in the struggle with poverty" was delivered by the Associate Professor Jacek Kucharski, Ph.D., D.Sc., Professor of Łódź University of Technology, the Dean of the Faculty of Electrical, Electronic, Computer and Control Engineering. The successive speaker was Janusz Steinhoff, the Vice-Premier in the years 2000–2001 and the Minister of Economy in the period of 1997–2001. His lecture was entitled: "The sustainable development – engineering as the support in the struggle with poverty". The discussed part of the session was ended by the presentation "Protection of the professional title of engineer",

LAUREATES OF THE XXXIth PLEBISCITE OF THE "TECHNICAL REVIEW" READERS

ENGINEER OF THE JUBILEE YEAR OF FSNT-NOT

Prof. dr. hab. Tadeusz Pałko, Eng.,
Specialist in biomedical engineering from Warsaw University of Technology, the Chairman of Polish Committee of Biomedical Engineering of the Association of Polish Electrical Engineers

DIAMOND ENGINEER 2024

Prof. dr. hab. Krzysztof Zaremba
Electronic engineer, scientist specialized in nuclear electronics and biomedical engineering, academic teacher, Rector of Warsaw University of Technology

GOLDEN ENGINEERS 2024

Dr Mariusz Buława, Eng.
Electronic engineer, the President of the Board of voestalpine Signaling Poland, the member of the Association of Communication Engineers and Technicians of the Republic of Poland
Category: INFRASTRUCTURE

Prof. dr. hab. Rafał Dańko, Eng.
Engineer, specialized in casting, scientist and didactic teacher, Vice-Rector for Student Affairs at AGH Cracow, the President of Technical Association of Polish Casting Engineers
Category: SCIENCE

Dr Barbara Juszczyk, Eng.
Materials engineer, director of Łukasiewicz Institute of Non-ferrous Metals, the President of the Association of Engineers and Technicians of Non-ferrous Metals
Category: INNOVATIVENESS

Prof. dr hab. Józef Korbicz, Eng.
Specialist in the field of automation, robotics and information science, professor of Zielona Góra University, the Full Member of the Polish Academy of Sciences (PAN)
Category: INFOTECHNOLOGIES

Engineer Piotr Mazurczyk, M.Sc.
Engineer of organization and management, with the specialization automotive industry, head of department of logistics at Factory of Fasteners Bispol Ltd, belonging to ASMET Group
Category: MANAGER

Dr Piotr Szymczak, Eng.
Electrical engineer, long-time President of the Association of Polish Electrical Engineers, popularizer of history of outstanding Polish electricians
Category: ASSOCIATION ACTIVIST

SILVER ENGINEERS 2024

Prof. dr hab. Andrzej Kolasa, Eng.
Mechanical engineer, co-organizer of the National Higher Vocational School in Ciechanów and Mława, the Member of the Association of Graduates and Friends of Warsaw University of Technology
Category: SCIENCE

Engineer Zbysław Antoni Kucza, M.Sc.
Electronics engineer, specialist of telecommunication, didactic-scientific worker at WSOWL in Zegrz, the member of the Association of Polish Electrical Engineers
Category: ASSOCIATION ACTIVIST

Engineer Tomasz Michalik, M.Sc.
Graduate of the Faculty of Production Engineering at the Warsaw University of Life Sciences (SGGW), technical director of SMP Poland Ltd, dealing with the design and the implementation of the products for automotive industry
Category: INNOVATIVENESS

Engineer Michał Mitrut, M.Sc.
Construction engineer, connected with the construction of the railway and road infrastructure, founder and director of the Central Railway and Road Laboratory
Category: INFRASTRUCTURE

Dr Małgorzata Muzalewska, Eng.
Mechanical engineer with specialization biomedical engineering, research worker of Silesia University of Technology, co-author of patents and many scientific publications
Category: BIOTECHNOLOGY

Engineer Jakub Nowopolski, MSc. in architecture
Architect, he manages his own design study KONCEPT, the member of the Pomerania Regional Chamber of Architects, he possesses the construction entitlements for designing without limitations
Category: ARCHITECTURE

THE DISTINGUISHED ENGINEERS 2024

Dr Bogdan Bogdański, Eng.
Mechanical engineer, co-founder of the National Association of the Occupational Safety and Health Service Workers, the member of SIMP and SPWiR, awarded with many association distinctions
Category: INNOVATIVENESS

Engineer Roman Długi, Msc.
Automation, mechanical and power engineer, creator and owner of ASKET company, specialized in renewable energy in rural environment
Category: POWER INDUSTRY

Dr hab. Artur Kozłowski, Eng., the Institute Professor
Manager, scientist, expert in the field of new technologies and cyber safety, Vice-President of the SEP Department of the Coal Basin
Category: MANAGER

Engineer Renata Łabędź, MSc.
Engineer of environment protection, she has the constructional rights, acts in the Małopolska Regional Chamber of Construction Engineers, the President of NOT SFNF Council in Tarnów
Category: ECOLOGY

Engineer Krystyna Popiel, MSc.
Agricultural engineer, property expert, the member of NOT, SITR and the Council of Entrepreneurship of the Pomerania Voivodeship, she maintains active contacts with the Polish engineering organizations outside Poland
Category: ASSOCIATION ACTIVIST

Prof. Dr hab. Lidia Żakowska, Eng.
She is specialized in land engineering and road transport problems, scientific worker of Cracow University of Technology; the author of more than 100 scientific publications; she runs the activity in SITK RP and FSNT-NOT
Category: SCIENCE

YOUNG ENGINEERS 2024

Engineer Michał Cichowicz, MSc.
Graduate of 3 specialization faculties: automation and robotics, electrical engineering, mechanical engineering and machine construction; Ph. D. candidate at the West-Pomerania Technological University, the member of SEP

Engineer Maria Sajdak, MSc.
Materials engineer, Ph.D. candidate at the Faculty of Material Engineering and Ceramics at AGH in Cracow, sportswoman (rowing), the vice-champion of Europe 2016, World and Europe Champion in 2018, the World Champion (2017, 2019) silver medal holder of the Olympian Games, Tokio 2020

Engineer Michalina Zając, MSc.
Mechanical engineer, graduate of Łódź University of Technology, laureate of the 22nd edition of the National Competition for diploma and award of the President of SIMP for the best diploma paper of mechanical profile

HONORARY GOLDEN ENGINEERS 2024

Engineer Małgorzata Bartoszewska, MSc.
Wood technologist, manager, the main specialist for investments and renovations at the Polski Theatre in Warsaw

Dr hab. Danuta Zawadzka, the university professor
Economist, academic teacher, from the period of studies she is connected with the Koszalin University of Technology, since 2020 – the Rector of the Koszalin University of Technology

Engineer Hanna Zdanowska, MSc.
Engineer of environment, self- governing activist, politician, the deputy to the Seym (Polish Parliament) of the 6th cadency, since 2010 – the President of Łódź

delivered by Prof. Jerzy Barglik, Ph.D., D.Sc., the President of Engineering Academy in Poland.

The solemn Gala was the emotional part of the celebrations of the Engineer's Day. It was the moment when the outstanding representatives of the engineering environment were distinguished with the awards. Diplomas and statuettes for the laureates of the 31st edition of the plebiscite for the title of "Golden Engineer of Technical Review" were jointly handed by the Vice-Minister of Sciences, Prof. Marek Gzik, Ewa Mańkiewicz-Cudny, Prof. Krzysztof Jóźwik, the Rector of Łódź University of Technology and Jolanta Czudak-Tomaka, the Editor-in-Chief of the 159th years old "Technical Review". The list of the Laureates is enclosed to the present paper.

It is worthy to distinguish some special laureates of the 31st plebiscite: the Engineer of the Jubilee Year of FSNT-NOT, prof. Tadeusz Pałko, Ph.D., D.Sc. – the prominent specialist in biomedical engineering from the Institute of Metrology and Biomedical Engineering of Warsaw University of Technology, and Diamond Engineer, Prof. Krzysztof Zaremba, Ph.D., D.Sc., (Hirsch Index 57), the Rector of Warsaw University of Technology, laureate of many awards and distinctions.

We should also mention the laureates of the title of Honorary Golden Engineer, being granted – since the 10th edition of the plebiscite, to the graduates of technical universities who gained the success in completely different domains but also to the persons with non-technical education who had contributed to the development of modern technologies or to their popularization.

The title of the Honorary Golden Engineer went to Małgorzata Bartoszewska, M.Sc., – engineer of wood technology, the main specialist for investments at the Polski Theatre in Warsaw; she links technical education and other domains of knowledge.

The title of Honorary Golden Engineer was also awarded to Dr Danuta Zawadzka, Ph.D. – not only professor but also Her Magnificence Rector of Koszalin University of Technology, the specialist in finances and banking, Deputy President of KRPUT and, also, the member of the Committee of Sciences on Finances of Polish Academy of Sciences, the member of Polish Economic Society, Polish Association of Finances and Banking and the Chairwoman of the Scientific Council at the Institute of Health SOFRA.

The third title of the Honorary Golden Engineer went to engineer Hanna Zdanowska, M.Sc., the President of Łódź city, the graduate of Łódź University of Technology, engineer of environment self-governing activist, politician, the deputy to the Seym (the Parliament of Poland) of the 6th cadency; since December 2019 – the member of the European Committee of Regions, and also, of the Working Team of EKR Green Deal Going Local; the Ambassador of the Deal on Climate representing EKR and the National Ambassador for Agreement of Mayors.

At the end of the Gala, all laureates and the persons who handed the awards assembled to a group photo. After so many emotions, the deserved moment of rest had place during which the audience could listen to the concert of film hits played with four violin bows, presented by Opera String Quartet.

Source: https://not.org.pl/aktualnosci.swiatowy-dzien-inzyniera-10?department=centrala