Materials Research Proceedings 34 (2023) 268-277 https://doi.org/10.21741/9781644902691-32

Commercialization of Research Results – Overview of Assumptions and General Definitions

JAGUSIAK-KOCIK Marta [1,a *] and JANASIK Michał [2,b]

[1] Czestochowa University of Technology, Department of Production Engineering and Safety, Armii Krajowej 19B, 42-201 Czestochowa, Poland

[2] Łukasiewicz Centre, 19 Poleczki street, 02-822 Warsaw, Poland

[a]m.jagusiak-kocik@pcz.pl*

Keywords: Scientific Network, Commercialization of Research Results, Indirect Commercialization, Direct Commercialization, Financing of Commercialization

Abstract. The work is based on a literature review in the field of commercialization of scientific research – it presents various definitions of commercialization, the concept of indirect and direct commercialization, as well as ways of financing the commercialization of research results. The aim of the work is to present and learn about various approaches to the concept of commercialization, to show what forms the process of commercialization of research results takes place and how it can be financed. The aim is to identify and analyze the research area, because the work is an introduction to practical research and the creation of a model for the commercialization of scientific research results in the largest research network in Poland, dealing with i.e. providing attractive and competitive technological solutions.

Introduction

The commercialization of research results is the foundation of cooperation between science and business/industry [1]. It is necessary to properly structure it (based on international experience in the field of best practices) in order to successfully implement projects that will involve both representatives from the world of science and the world of industry. Important from the point of view of proper planning of all activities preceding successful commercialization, and then its proper implementation, is the choice of the method of commercialization and, among others, defining the form of intellectual property protection [1]. The subject of commercialization of scientific research results is any product or service produced in a scientific unit as a result of research conducted there [2]. This is a very important issue in the realities of the knowledge economy, because it translates into the competitive position of the national economy in the era of globalization [3].

The aim of the work is to present the concept of commercialization according to various authors, to present the forms of indirect and direct commercialization as well as to present the method of financing commercialization. By recognizing the topic and analyzing the available literature, research related to the analysis of commercialization models will be possible and an attempt to create a model for the commercialization of research results in the largest research network in Poland.

The Concept of Commercialization

One of the first definitions of the term commercialization in the Polish legal system appeared in the Act of August 30th, 1996 on commercialization and privatization of enterprises (UKPP). According to this definition, commercialization consists in transforming a state-owned enterprise into a company; unless the provisions of the Act provide otherwise, this company enters into all legal relationships of which the state-owned enterprise was the subject, regardless of the legal nature of these relationships [4]. After 2000, when the importance of innovation policy and the use

of the potential of Polish science to increase the competitiveness of enterprises began to grow, and the privatization of state-owned enterprises was practically completed, the concept of commercialization in the Polish legal system changed and was linked with the commercialization of the results of research activity [4]. In 2014, in the Law Act on higher education (UPSW), the concept of indirect and direct commercialization appeared. These concepts and the division were maintained in Act 2.0 Law on Higher Education and science, in Chapter 6, on Commercialization of the results of scientific activity and know-how. According to the Dictionary of Foreign Words and Foreign Language Phrases, "commercialization" (from Middle Latin *commercialis* – commercial, from Latin *commercium* – trade in goods, from English commerce – trade or trade exchange) is basing something on commercial, mercantile principles [4, 5]. According to this definition, commercialization is making something marketable, making it possible to buy it on the market and that someone has to pay for it [5-7]. Commercialization is defined as the transfer (transfer) of knowledge, ideas, research results from research laboratories to the market [5, 6, 8-10] – that is, it is supplying the market with new solutions. According to the National Center for Research and Science, commercialization is all activities related to the transfer of research results to economic and social practice, i.e., the transfer and sale by science institutions of a given technical or organizational knowledge and related know-how to the business sphere [4, 11, 12]. Commercialization is the process of creating added value for ideas, research results, technologies and new products, the spread of innovations within economies and industry sectors. It is building a business model for a current or future organization based on new technologies or new products. It results from patterns adopted and shaped by technological and innovation policy [13-16].

Other notions of commercialization can also be found in the literature, such as [4-6, 12, 17, 18]:

- Webster's Third New International Dictionary: Commercialization is to ensure that a product or technology with the potential to be produced, presented, sold, and used brings added value, profits and increases the company's capital.
- J.R. Meredith, S.M. Shafer: Commercialization is the process of transferring ideas into a new product or service from the conception of the product to its launch on the market.
- D.R. Prebble, G. A. de Waal, C. de Groot: Commercialization is something between innovation and entrepreneurship. It includes processes and activities that fill the gap between the creation of economic added value and the realization of economic added value.
- M.J. DeGeeter: Successful commercialization is a complex process dependent on many factors (inputs to the process) skilfully managed in order to create appropriate and prudent strategic and tactical plans to be implemented effectively and efficiently.
- K.B. Matusiak: Commercialization is all activities related to the transfer of a given technical or organizational knowledge and related know-how to business practice. Technology commercialization can be defined as the process of supplying the market with new technologies.

Methods of Commercialization of Research Results

Commercialization can take many forms. These forms are not established once and for all, which is why new types of transferring knowledge to the economy are often found in economic practice [19, 20]. Commercialization may take the form of indirect or direct commercialization [4, 7, 19].

According to the National Center for Research and Development, direct commercialization is a process in which the right to R&D results grants a license directly to the entity implementing these results, e.g., for production according to a patent and using know-how, or sells rights [4]. In direct commercialization, the creator of a new solution makes it available to other people or companies (i.e., he gives ownership rights to the innovation that is protected by a patent). Then, these companies or people introduce the new idea into practice on their own (the market is exploited and benefits from the competitive advantage offered by this innovation are taken). The process of direct commercialization may consist in the sale of exclusive rights or granting licenses

and collecting license fees. Sieńczyło-Chlabicz [21] defines direct commercialization as based on the legislator listing exemplary forms of making research results available to a third party. In direct commercialization, this form is an agreement, which is connected with a regulation or authorization to exploit an intangible asset. Direct commercialization is the sale of the results of scientific research, development work or know-how related to these results, or making these results or know-how available for use, in particular on the basis of a license, rental or lease agreement [4].

The consequence of direct commercialization is that the results of scientific research gain contact with the market - they are offered to third parties (buyers, licensees) for use or purchase. Through this form of commercialization, the entity that exclusively uses the results of scientific research is not only the scientific unit that produced them.

Direct commercialization can take place in two ways:

- sale of research and development results,
- granting a license for the results of research and development works.

Direct commercialization has many benefits, but also carries certain risks. The formula of this form of commercialization enables the "cross" benefit from different specializations that are held by both parties. And so, the creator of innovation (innovator) gains access to future income, which is generated by the entity undertaking the market exploitation of innovation (licensee), and the licensee has access to innovation, which he would not be able to produce himself or such production would require disproportionately large expenditures.

Licensing [22] consists in authorizing another entity to use the results of R&D works in a specific scope and time of use. The license agreement specifies in detail and in writing, the scope of the authorization to use the invention, which is granted by the patent holder to another entity. They make it possible for the relationship between the entity that grants the license and the licensee to be shaped in a variety of ways. For the licensor, the main source of profit (benefits) are license fees. There are at least six types of licenses [12] – different types of intellectual property rights are associated with them. They are not separable and may occur in several variants together, e.g. a non-exclusive license may be full or limited.

The sale of property rights [22] is a common form of commercialization of developed technologies. One of its forms is the sale of only know-how regarding a given technology and the right to use it by the buyer. In this case, the concept itself is subject to sale. Intellectual property rights can in most cases be freely traded. Acquisition and disposal (e.g. sale) of proprietary copyrights requires the conclusion of a contract.

Indirect commercialization is a more complex and advanced process than direct commercialization. In this commercialization, the creator of the innovation (originator) is involved in the process of implementing this innovation on the market by creating a business entity (the originator launches it alone or with partners), through which the given solution will be implemented in business practice [21]. The goal is to start market production, which is based on an innovation that is the intellectual property of its creator. In this way, the “intermediary” (licensee) is avoided, which stands in the case of direct commercialization between the creator of the innovation and the market. The creator of the innovation takes responsibility for the course of all stages of the commercialization process, which results in successfully introducing the innovation to the market, developing it and maintaining it on this market for a certain period of time. The creator of innovation should have new skills and qualifications and be aware that risk is a feature of commercialization. Indirect commercialization takes place through established companies [4]. Shares in companies are subscribed for or purchased, or subscription warrants are subscribed for, which entitle to subscribe for shares in companies. The goal is to implement or prepare for implementation the results of scientific research, development works or know-how related to these results.

Materials Research Proceedings 34 (2023) 268-277 https://doi.org/10.21741/9781644902691-32

A company is a business enterprise which is carried out by two or more persons and managed by them. Companies are one of the organizational and legal forms under which enterprises operate. Contrary to direct commercialization, in this form of commercialization there is no real contact between research results and the market. According to the definition of the National Center for Research and Development [4], indirect commercialization takes the following forms:

- formation of a company,
- transfer of intellectual property rights to the company,
- another form of indirect commercialization.

Among the commercial companies (they are divided into partnerships and capital companies), which are established by the State Research Units (PJB), there are:

- general partnership,
- professional partnership,
- limited partnership,
- limited joint-stock partnership,
- limited liability company,
- joint-stock company,
- a simple joint-stock company.

General partnerships, professional partnerships, limited partnerships and limited joint-stock partnerships are partnerships, while limited liability companies, joint-stock companies and simple joint-stock companies are capital companies. Commercial companies are registered in the Register of Entrepreneurs in the National Court Register (KRS). There are two methods of submitting an application for registration in the National Court Register:

- via the S24 system - in the case of companies whose agreement was concluded in this system (this system can be used to establish a general partnership, limited partnership, limited liability company and a simple joint-stock company),
- through the Court Registers Portal - in the case of companies whose agreement has been concluded in traditional form.

At the moment of registration in the National Court Register, capital companies acquire legal personality and partnerships are established. State Research Units (PJB), by co-creating a given company, derive financial and corporate benefits from it, but it is impossible for them to create partnerships, because such companies can only be established by natural persons to practice a freelance profession. Each capital company has characteristics such as:

- full legal personality,
- share capital held,
- liability borne by the company (management board and supervisory board), and not by its shareholders,
- the accumulated assets are separate from the personal assets of partners or shareholders,
- separation of the ownership sphere and the management sphere (this means that the company is run by its governing bodies, not partners or shareholders).

The governing bodies of capital companies include:

- management board - it implements decisions made by shareholders and persons representing the company,
- supervisory board or audit committee – its task is to supervise the company's operations,
- general meeting or shareholders' meeting – makes the most important decisions in the company.

Materials Research Proceedings 34 (2023) 268-277 https://doi.org/10.21741/9781644902691-32

Financing the Commercialization of Research Results

The financing process consists of all undertakings in the company that provide the company with capital, and also shape the entire structure of financing sources in given market conditions. The financing strategy, including the acquisition of specific sources of financing for the company, is an expression of the entire financing process. The elements of the financing process are:

- financing objectives,
- principles of financing business operations,
- methods and tools used to achieve particular goals and principles,
- stages of the financing process.

The commercialization process of research results encompasses various stages, and while they may vary in practice, they share certain common characteristics from a financial perspective. The research and development stage [12] is characterized by expenses without generating any revenues. During this stage, companies invest in research projects, testing developed solutions, and prototyping, but there is no income generated. This stage poses a double burden for companies as it involves significant financial outlays for laboratory and research equipment, materials, and staffing expenses. Additionally, it prolongs the time between project initiation and the generation of sales revenue. As a result, entrepreneurs, whenever possible, tend to avoid this stage and explore alternative options such as acquiring technology from external sources. The stage of implementation and introduction to the market [12] is a stage that includes activities such as:

- undertaking an investment – to produce a new product or provide a new service involves significant expenses, including factors such as production costs,
- introducing a product or service to the market – involves financial resources for manufacturing, promotion, and establishing distribution channels.

The stage of sales development [12] refers to the period when a new product or service gains acceptance in the market, resulting in increasing revenue. During this stage, the sales cover the operating costs associated with producing the product or delivering the service. For projects that involve further development and expansion into new markets, additional financial resources are required. However, projects that do not aim for dynamic growth can reach a satisfactory operational scale and generate profits. Obtaining external financing for a project related to the commercialization of new solutions requires significant commitment from the implementing entity. It can be challenging due to factors such as the skepticism of capital providers. In the early stages of implementing technical solutions, external financing options include *business angels* (individual investors) and seed capital. Business angels are experienced individuals who have successfully developed their own businesses and are willing to invest in the ideas of new creators, start-ups, and early-stage enterprises. They not only provide financial support but also offer mentorship, scientific guidance, and valuable networking opportunities. In return, business angels become shareholders in the company. *Seed funds* are initial-stage investment funds that focus on investing in early implementation or planning phase ideas and receive equity in return. These funds not only provide capital but also offer valuable knowledge and mentorship. They are managed by experienced investors who possess industry contacts and expertise in entering the market and gaining a competitive edge. When it comes to financing innovative projects based on new technical solutions, industrial enterprises can serve as potential sources of investment. They can provide capital as strategic investors or corporate venture capitalists. The banking sector is the main provider of capital to enterprises, however, when it comes to financing innovative projects, banks are cautious and their financing can only be used for advanced projects. Banks assess the company's creditworthiness and a sufficient level of collateral – these conditions are usually met by companies with a relatively long market history and good financial standing [24].

Areas of Commercialization in STEM Sciences

The commercialization of scientific research results must have economic value for stakeholders, meaning it must either significantly improve the quality of products and services [25-27] or reduce costs, including the management of production and service processes [28]. Scientific outcomes in the STEM field are typically associated with either typical material-related problems within the scope of materials engineering [29-31], especially in the case of special alloys [32, 33], or machine-related issues [34, 35], which encounter specific problems beyond the competence and cognition of an average engineer, particularly in the railway industry [36], issues related to wear [37], including fatigue of welded joints [38, 39] and hydraulic power systems [40]. The demand for scientific support also arises in the case of particularly advanced technologies associated with coatings [41-43] and surface layer [44]. This primarily includes DLC coatings [45-47] and ESD coatings [48-50], as well as separation issues [51]. In any of these cases, analytical and statistical support is necessary [52], including experimental design methodology [53-55] and non-classical approaches [56-58]. In the case of a large set of controlled factors, prior dimensionality reduction [59] is also necessary.

Summary

In the process of effective commercialization that brings measurable financial benefits (taking the form of direct and indirect commercialization), the basis is sales, implementation on the market using market principles and its practical use in economic turnover. Therefore, already at an early stage of this process, it is necessary to precisely define the commercialization strategy and carefully and thoroughly identify barriers and risks that may delay this process (thus reducing the entire commercialization potential or economic value of intellectual property), or in extreme cases prevent it. These barriers may relate to technological, legal and economic areas [23, 24]. This will make intellectual property an innovative and perhaps even groundbreaking technology.

References

[1] M. Makowiec. Start-upy technologiczne generujące innowacje w gospodarce jako efekt komercjalizacji badań naukowych. Nierówności Społeczne a Wzrost Gospodarczy 4 (2017) 424-441. https://doi.org/10.15584/nsawg.2017.4.31

[2] B. Flisiuk, A. Gołąbek. Commercialization of research results – models, procedures, barriers and best practices, Zeszyty Naukowe. Organizacja i Zarządzanie / Politechnika Śląska 77 (2015) 63-73.

[3] U. Mikiewicz. Problems of management of special purpose vehicles set up by the local government and scientific institutions to commercialize research – case study, Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu 543 (2018) 98-109.

[4] M.J. Radło, M. Baranowski, T. Napiórkowski, J. Chojecki. Komercjalizacja, wdrożenia i transfer technologii. Definicje i pomiar. Dobre praktyki wybranych krajów, Oficyna Wydawnicza SGH, Narodowe Centrum Badań i Rozwoju, Warszawa, 2020. ISBN 978-8380303942

[5] E. Gwarda-Gruszczyńska. Strategie przedsiębiorstw a ochrona własności intelektualnej, in: D.M. Trzmielak (Ed.), Komercjalizacja wiedzy i technologii a własność intelektualna, Centrum Transferu Technologii Uniwersytetu Łódzkiego, Łódź, 2010.

[6] T.B. Kalinowski. Modele komercjalizacji i transferu technologii, in: D.M. Trzmielak (Ed.), Komercjalizacja wiedzy i technologii a własność intelektualna, Centrum Transferu Technologii Uniwersytetu Łódzkiego, Łódź, 2010.

[7] D. Markiewicz. Komercjalizacja wyników badań naukowych – krok po kroku. Centrum Transferu Technologii Politechnika Krakowska, Kraków, 2009.

[8] A. Białek-Jaworska, R. Gabryelczyk, A. Pugacewicz. Czy komercjalizacja wyników badań naukowych wpływa na dojrzałość modelu biznesowego? Przedsiębiorczość i Zarządzanie 16 (2015) 91-108.

[9] S. Thore. Technology Commercialization: DEA and Related Analytical Methods for Evaluating the Use and Implementation of Technical Innovation, Boston-Dordrecht-London, Kluwer Academic Publishers, 2002. https://doi.org/10.1007/978-1-4615-1001-7

[10] B. Poteralska, M. Walasik. Commercialisation Models for R&D Organisations, ECIE 2021 Proc. 16th Eur. Conf. Innov. Entrepreneurship 2 (2021) 782-290. https://doi.org/10.34190/EIE.21.118

[11] W. Gaweł. Komercjalizacja badań naukowych pomiędzy powinnością a niezależnością nauki, in: K. Karpińska, A. Protasiewicz (Eds.), Współczesne problemy ekonomiczne w badaniach młodych naukowców. T.1, Wzrost, rozwój i polityka gospodarcza, Polskie Towarzystwo Ekonomiczne, 196-206, 2018.

[12] S. Łobejko, A. Sosnowska (Eds.). Komercjalizacja wyników badań naukowych praktyczny poradnik dla naukowców. Urząd Marszałkowski Województwa Mazowieckiego w Warszawie, Departament Rozwoju Regionalnego i Funduszy Europejskich, Wydział Innowacyjności, Warszawa, 2013.

[13] D.M. Trzmielak. Współpraca ośrodków naukowych i przedsiębiorstw we wdrażaniu wyników badan, in: W. Wiśniowski (Ed.), Marketing instytucji naukowych i badawczych, Prace Instytutu Lotnictwa, Warszawa, 2013.

[14] D.M. Trzmielak. Komercjalizacja wiedzy i technologii – determinanty i strategie. Wydawnictwo Uniwersytetu Łódzkiego, Łódź, 2013. ISBN 978-8379691401

[15] D. Avimanyu, M. Debmalya, J. Len. Understanding commercialization of technological innovation: Taking stock and moving forward. R&D Manag. 45 (2015) 215-249. https://doi.org/10.1111/radm.12068

[16] R. Svensson. Commercialization, renewal, and quality of patents, Econ. Innov. New Technol. 21 (2012) 175-201. https://doi.org/10.1080/10438599.2011.561996

[17] V.Virchenko et al. Commercialization of intellectual property: innovative impact on global competitiveness of national economies. Market. Manag. Innov. 5 (2021) 25-39. https://doi.org/10.21272/mmi.2021.2-02

[18] B.M. Frischmann. Commercializing University Research System in Economic Perspective: a View from the Demand Side, in: G.D. Libecap (Ed.) University Entrepreneurship and Technology Transfer: Process, Design, and Intellectual Property, Emerald, 2005, 155-186. http://doi.org/10.1016/S1048-4736(05)16006-8

[19] P. Głodek. Akademicki spin off. Wiedza, zasoby i ścieżki rozwoju. Wydawnictwo Uniwersytetu Łódzkiego, Łódź, 2019. ISBN 978-8381425605

[20] T. Dehghani. Technology commercialization: From generating ideas to creating economic value. Int. J. Organ. Leadersh. 4 (2015) 192-199. https://doi.org/10.33844/IJOL.2015.60449

[21] D. Dec, K. Dobrowolska (Eds.). Badanie w zakresie przedsiębiorczości akademickiej i spin-off, w tym programów akademickich dotyczących przedsiębiorczości i funkcjonowania uczelnianych jednostek promujących przedsiębiorczość akademicką, Raport końcowy z badania, Urząd Marszałkowski Województwa Mazowieckiego, Warszawa 2014.

[22] G.D. Markman, D.S. Siegel, M. Wright. Research and Technology Commercialization. J. Manag. Stud. 45 (2008) 1401-1423. https://doi.org/10.1111/j.1467-6486.2008.00803.x

[23] T. Caulfield, U. Ogbogu. The commercialization of university-based research: Balancing risks and benefits, BMC Med. Ethics 16 (2015) art.70. https://doi.org/10.1186/s12910-015-0064-2

[24] K.B. Matusiak, J. Guliński (Eds.) System transferu i komercjalizacji wiedzy w Polsce – siły motoryczne i bariery. PARP, Warszawa, 2010. ISBN 978-8376330013

[25] S. Borkowski et al. The use of 3x3 matrix to evaluation of ribbed wire manufacturing technology, METAL 2012 – 21st Int. Conf. Metallurgy and Materials (2012), Ostrava, Tanger 1722-1728.

[26] D. Siwiec et al. Improving the non-destructive test by initiating the quality management techniques on an example of the turbine nozzle outlet, Materials Research Proceedings 17 (2020) 16-22. https://doi.org/10.21741/9781644901038-3

[27] T. Lipiński, R. Ulewicz. The effect of the impurities spaces on the quality of structural steel working at variable loads, Open Eng. 11 (2021) 233-238. https://doi.org/10.1515/eng-2021-0024

[28] P. Fobel, A. Kuzior. The future (Industry 4.0) is closer than we think. Will it also be ethical? AIP Conf. Proc. 2186 (2019) art. 80003. https://doi.org/10.1063/1.5137987

[29] P. Szataniak et al. HSLA steels - Comparison of cutting techniques, METAL 2014 - 23rd Int. Conf. Metallurgy and Materials (2014), Ostrava, Tanger, 778-783.

[30] A. Szczotok et al. The Impact of the Thickness of the Ceramic Shell Mould on the (γ + γ′) Eutectic in the IN713C Superalloy Airfoil Blade Casting, Arch. Metall. Mater. 62 (2017) 587-593. https://doi.org/10.1515/amm-2017-0087

[31] D. Klimecka-Tatar, R. Dwornicka. The assembly process stability assessment based on the strength parameters statistical control of complex metal products, METAL 2019 – 28th Int. Conf. Metall. Mater. (2019) 709-714. ISBN 978-808729492-5

[32] P. Jonšta et al. The effect of rare earth metals alloying on the internal quality of industrially produced heavy steel forgings, Materials 14 (2021) art.5160. https://doi.org/10.3390/ma14185160

[33] A. Dudek et al. The effect of alloying method on the structure and properties of sintered stainless steel, Arch. Metall. Mater. 62 (2017) 281-287. https://doi.org/10.1515/amm-2017-0042

[34] R. Ulewicz, M. Mazur. Economic aspects of robotization of production processes by example of a car semi-trailers manufacturer, Manuf. Technol. 19 (2019) 1054-1059. https://doi.org/10.21062/ujep/408.2019/a/1213-2489/MT/19/6/1054

[35] S. Blasiak et al. Rapid prototyping of pneumatic directional control valves, Polymers 13 (2021) art. 1458. https://doi.org/10.3390/polym13091458

[36] N. Radek, R. Dwornicka. Fire properties of intumescent coating systems for the rolling stock, Commun. – Sci. Lett. Univ. Zilina 22 (2020) 90-96. https://doi.org/10.26552/com.C.2020.4.90-96

[37] S. Marković et al. Exploitation characteristics of teeth flanks of gears regenerated by three hard-facing procedures, Materials 14 (2021) art. 4203. https://doi.org/10.3390/ma14154203

[38] N. Radek et al. The impact of laser welding parameters on the mechanical properties of the weld, AIP Conf. Proc. 2017 (2018) art. 20025. https://doi.org/10.1063/1.5056288

[39] N. Radek et al. Properties of Steel Welded with CO_2 Laser, Lecture Notes in Mechanical Engineering (2020) 571-580. https://doi.org/10.1007/978-3-030-33146-7_65

[40] G. Filo et al. Modelling of pressure pulse generator with the use of a flow control valve and a fuzzy logic controller, AIP Conf. Proc. 2029 (2018) art.20015. https://doi.org/10.1063/1.5066477

[41] N. Radek et al. Technology and application of anti-graffiti coating systems for rolling stock, METAL 2019 28th Int. Conf. Metall. Mater. (2019) 1127-1132. ISBN 978-8087294925

[42] N. Radek et al. The effect of laser beam processing on the properties of WC-Co coatings deposited on steel. Materials 14 (2021) art. 538. https://doi.org/10.3390/ma14030538

[43] N. Radek et al. Formation of coatings with technologies using concentrated energy stream, Prod. Eng. Arch. 28 (2022) 117-122. https://doi.org/10.30657/pea.2022.28.13

[44] N. Radek et al. The influence of plasma cutting parameters on the geometric structure of cut surfaces, Mater. Res. Proc. 17 (2020) 132-137. https://doi.org/10.21741/9781644901038-20

[45] N. Radek et al. Microstructure and tribological properties of DLC coatings, Mater. Res. Proc. 17 (2020) 171-176. https://doi.org/10.21741/9781644901038-26

[46] N. Radek et al. Influence of laser texturing on tribological properties of DLC coatings, Prod. Eng. Arch. 27 (2021) 119-123. https://doi.org/10.30657/pea.2021.27.15

[47] N. Radek et al. Operational properties of DLC coatings and their potential application, METAL 2022 – 31st Int. Conf. Metall. Mater. (2022) 531-536. https://doi.org/10.37904/metal.2022.4491

[48] N. Radek, K. Bartkowiak. Laser Treatment of Electro-Spark Coatings Deposited in the Carbon Steel Substrate with using Nanostructured WC-Cu Electrodes, Physics Procedia 39 (2012) 295-301. https://doi.org/10.1016/j.phpro.2012.10.041

[49] N. Radek et al. The morphology and mechanical properties of ESD coatings before and after laser beam machining, Materials 13 (2020) art. 2331. https://doi.org/10.3390/ma13102331

[50] N. Radek et al. The impact of laser processing on the performance properties of electro-spark coatings, 14th World Congr. Comput. Mech. and ECCOMAS Congr. 1000 (2021) 1-10. https://doi.org/10.23967/wccm-eccomas.2020.336

[51] M. Zenkiewicz et al. Electrostatic separation of binary mixtures of some biodegradable polymers and poly(vinyl chloride) or poly(ethylene terephthalate), Polimery 61 (2016) 835-843. https://doi.org/10.14314/polimery.2016.835

[52] L. Cedro. Model parameter on-line identification with nonlinear parametrization – manipulator model, Technical Transactions 119 (2022) art. e2022007. https://doi.org/10.37705/TechTrans/e2022007

[53] J. Pietraszek et al. The fixed-effects analysis of the relation between SDAS and carbides for the airfoil blade traces. Arch. Metall. Mater. 62 (2017) 235-239. https://doi.org/10.1515/amm-2017-0035

[54] R. Dwornicka, J. Pietraszek. The outline of the expert system for the design of experiment, Prod. Eng. Arch. 20 (2018) 43-48. https://doi.org/10.30657/pea.2018.20.09

[55] J. Pietraszek et al. Challenges for the DOE methodology related to the introduction of Industry 4.0. Prod. Eng. Arch. 26 (2020) 190-194. https://doi.org/10.30657/pea.2020.26.33

[56] J. Pietraszek. The modified sequential-binary approach for fuzzy operations on correlated assessments, LNAI 7894 (2013) 353-364. https://doi.org/10.1007/978-3-642-38658-9_32

[57] J. Pietraszek et al. Non-parametric assessment of the uncertainty in the analysis of the airfoil blade traces, METAL 2017 – 26th Int. Conf. Metall. Mater. (2017) 1412-1418. ISBN 978-8087294796

[58] J. Pietraszek et al. The non-parametric approach to the quantification of the uncertainty in the design of experiments modelling, UNCECOMP 2017 Proc. 2nd Int. Conf. Uncert. Quant. Comput. Sci. Eng. (2017) 598-604. https://doi.org/10.7712/120217.5395.17225

[59] J. Pietraszek, E. Skrzypczak-Pietraszek. The uncertainty and robustness of the principal component analysis as a tool for the dimensionality reduction. Solid State Phenom. 235 (2015) 1-8. https://doi.org/10.4028/www.scientific.net/SSP.235.1