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SCIENCE AND INDUSTRY IN A COUNTRY OF CHANGES

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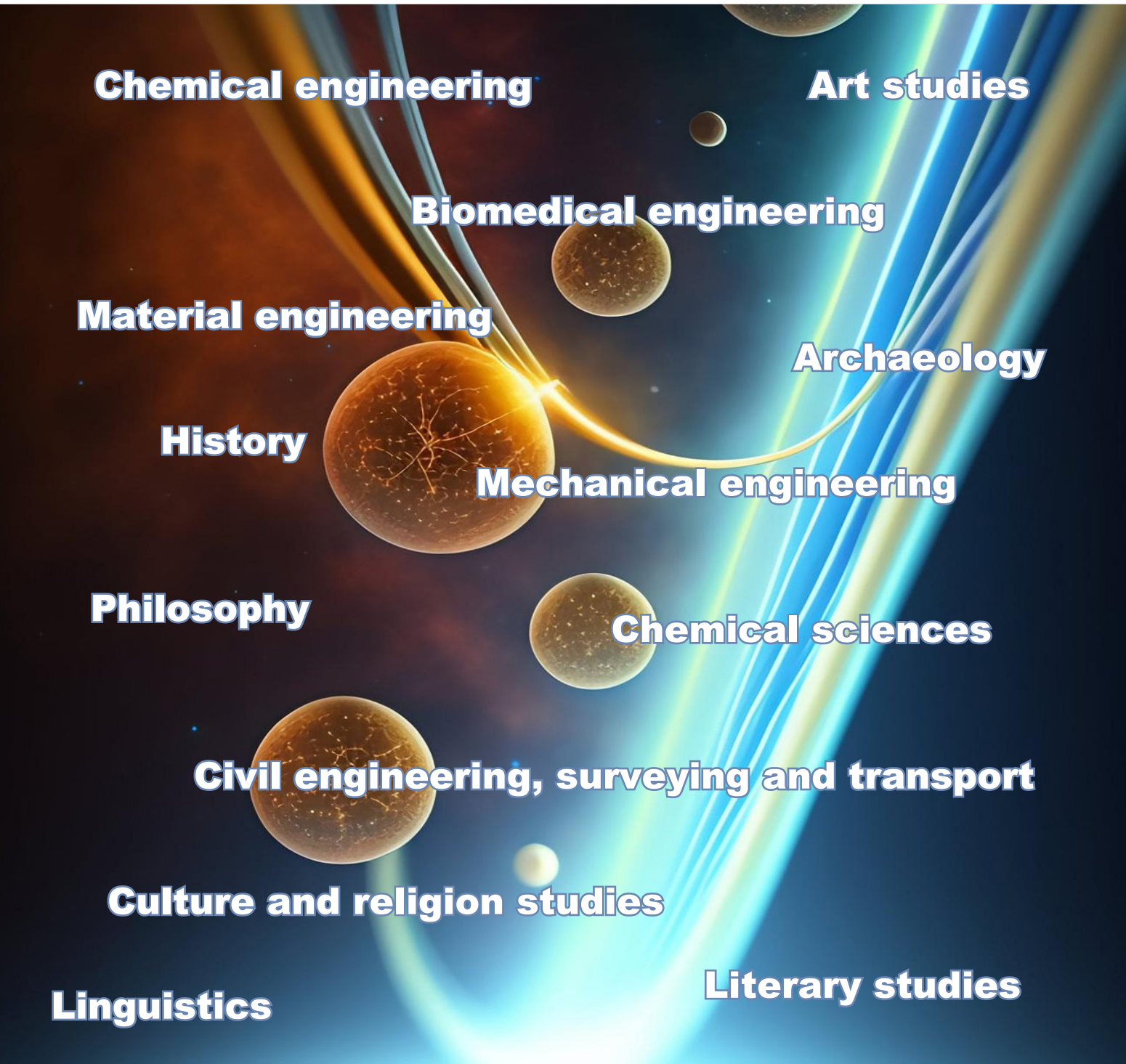

POLISH TECHNICAL REVIEW RECEIVED 40 POINTS ON THE LIST OF SCIENTIFIC JOURNALS OF THE MINISTRY OF EDUCATION AND SCIENCE

Dr hab. Dawid Myszka – new Editor in Chief of *Polish Technical Review*

Dr hab. Dawid Myszka (in 1999) by Warsaw University of Technology with distinction, obtaining the title of MSc. Eng. in specialization: Mechanical Engineering and Machine Construction. He defended his PhD in 2003 and obtained the degree of Doctor of Technical Sciences. His doctoral thesis obtained the First Award in the competition of FIAT Research Scientific Centre. In 2015, the Council of the Faculty of Production Engineering WUT granted him the degree of habilitated doctor of technical sciences (post-doctoral degree). The mentioned thesis was distinguished by the award for achievements in science, granted by the Rector of Warsaw University of Technology. Since 2017, he has been employed as a professor at the Warsaw University of Technology.

His scientific activity includes, first of all, work in the field of casting processes and the problems of heat treatment of metals and alloys. A lot of publications with his participation also present the results in the domain of surface engineering, biomedical engineering and composites. He has been the co-creator of laboratories of investment casting where some of the most interesting engineering works at the Faculty of Mechanical and Industrial Engineering of WUT were generated. They were expressed, inter alia, in the publications and student presentations.

Dawid Myszka is the author or co-author of more than 70 publications in peer-reviewed journals and 2 patents. He developed materials to 3 monographs in Polish and 1 in English. He managed or participated in 16 Polish and 2 international research projects and, also, he developed tens of expertises for the needs of industry. He is also the member of many organizations and associations in the country and abroad, such as, inter alia, World Foundry Organization, Polish Society of Materials Science, Commission of Foundry Engineering of Polish Academy of Sciences, Section of Technological Processes of Polish Academy of Sciences.

He participated in many national and international conferences and delivered the lectures on the greatest international forums (e.g. World Tribology Congress in Beijing – China, World Foundry Congress in Nagoya – Japan, European Congress and Exhibition on Advanced Materials and Processes EUROMAT); he was also invited to deliver the lectures, ordered by the international institutions, e.g. Central Metallurgical Research Institute in Cairo – Egypt, Zanardie Foderies – Italy, Centro Nional de Investigaciones Metalúrgicas in Madrit – Spain. He is a co-organizer of the international conference "Modern Stels and Iron Alloys" which is cyclically held in Warsaw, Poland and gathers the group of the most prominent scientists from all over the world. In 2002, he obtained the scholarship of Foundation for Polish Science (FNP). In 2019, he was honored with the Medal of the Commission of National Education for the special merits for education and with the title of Silver Engineer of the Polish Federation of Engineering Associations NOT. He possesses the certificate PRINCE 2, confirming his competences in the field of managing the projects and capabilities of organizing the work of the project teams.

Since 2000, Professor Myszka has been involved in organizational activities at the Warsaw University of Technology. He dealt, among others, with the development and editing of promotional and historical materials of the Faculty Production Engineering, but also with the promotion of Student Scientific Circles of the Warsaw University of Technology. In the years 2012-2020, he served as vice-dean, dealing with activities supporting the functioning of Polish- and English-speaking students at the University. He is the author and coordinator of study programs in the field of management and production engineering. He is also a reviewer of many diploma, doctoral and habilitation theses in the field of mechanical engineering and materials engineering. He also reviews articles for many world-class scientific journals.

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IS PHOTOVOLTAIC CAPABLE TO REPLACE HEAT POWER PLANTS IN THE FUTURE?

CZY FOTOWOLTAIKA JEST W STANIE ZASTĄPIĆ W PRZYSZŁOŚCI ELEKTROWNIE CIEPLNE?

Summary: *A sudden gain of power installed in Polish photovoltaics during the recent years has been undoubtedly a great surprise for all. From the marginal position few years ago photovoltaics has become the unquestionable leader in respect of the installed power value from among the different types of renewable electric energy sources. It is anticipated that in the current year, the total value of power installed in Polish photovoltaic system will exceed value of 15 GW, leaving far behind – in this respect - wind energetics, even not mentioning other renewable sources of electric energy. Obtaining such high results was mainly possible owing to the state subsidies, developed governmental programs but also to a common enthusiasm which was the share of broad masses of our society – possessing of own power plant on the roof of one's house became, at a certain moment, something fashionable and also, something which the majority of the owners of single family houses wanted to possess (at least to impress the neighbours). A specific euphoria which appeared in connection with the photovoltaics causes that there are announced extremely ambitious plans for its further development and the anticipated future values of the power installed in the photovoltaic panels make you feel dizzy. During the mentioned discussions, we forget that the heat power plants in Poland still constitute the basis of functioning of electric energy system. They produce still more than ca. ¾ of electric energy, produced in our country. Meanwhile, we may often and often meet the publicly announced opinion that heat power plants are no longer necessary because in the nearest future, the decided majority of the electric energy consumed in the country will come only and exclusively from renewable sources; the supreme role will be, of course, played by photovoltaics. Indeed, according to the respective decisions, which were once undertaken by the governmental authorities, most of the Polish coal-fired power plants will cease completely their activity as soon as during the nearest several years.*

The authors of the present paper undertake the attempt to answer the question: whether photovoltaics will be able to replace, in the future, Polish heat power plants, intended for liquidation. The answer to such question is univocally negative and not only due to the seasonality of electric energy production in photovoltaic installations but, first of all, due to the impossibility to introduce a very high power (order of tens of gigawatts) to electric network at the peak moment of its generation in photovoltaic installations. The necessary balancing of such high levels of power in the national electro-energetic system is also impossible. The authors try also to give the answer to the question: where we are now in respect of the degree of advancement of investments in photovoltaics and in connection with it, how much electric power may be additionally installed in Polish photovoltaic power plants. The next problem, undertaken by the authors is the attempt to estimate what percentage of the national demand on electric energy may be covered from photovoltaic installations, with the simultaneous economic justification.

Keywords: *electric power, heat power plants, renewable energy sources, photovoltaics*

Streszczenie: *Gwałtowny przyrost w ostatnich latach mocy zainstalowanej w polskiej fotowoltaice był bez wątpienia dla wszystkich sporym zaskoczeniem. Z pozycji jeszcze kilka lat temu wyraźnie marginalnej fotowoltaika wysunęła się obecnie pod względem wartości mocy zainstalowanej na niekwestionowanego lidera spośród różnego rodzaju odnawialnych źródeł energii elektrycznej. Przewiduje się, że w bieżącym roku całkowita wartość mocy zainstalowanej w polskiej fotowoltaice przekroczy wartość 15 GW, daleko dystansując pod tym względem energetykę wiatrową, a o innych odnawialnych źródłach energii elektrycznej nawet nie wspominając. Uzyskanie tak wysokiego wyniku stało się możliwe głównie dzięki dotacjom państwowym, rozbudowanym programom rządowym, ale także poprzez zwykły entuzjazm, który udzielił się szerokim masom naszego społeczeństwa – posiadanie na dachu jednorodzinnego domku własnej elektrowni stało się w pewnym momencie po prostu czymś modnym, a także czymś, co większość właścicieli budynków jednorodzinnych chciałaby koniecznie posiadać, chociażby po to, aby zaimponować swoim sąsiadom. Swoista euforia, która zapanowała wokół fotowoltaiki powoduje, że powszechnie głoszone są niezwykle ambitne plany dalszego jej rozwoju, a przewidywane w przyszłości wartości mocy zainstalowanej w panelach fotowoltaicznych przyprawiają wręcz o zawrót głowy. Podczas tego rodzaju dyskusji zapomina się, że w Polsce elektrownie cieplne nadal stanowią podstawę funkcjonowania systemu elektroenergetycznego i to właśnie w nich wytwarzane jest nadal około trzech czwartych produkowanej w naszym kraju energii elektrycznej. Tymczasem coraz częściej można spotkać się z wygłaszanymi na forum publicznym opiniami, że elektrownie cieplne nie są nam już więcej potrzebne, ponieważ w najbliższej przyszłości zdecydowana większość konsumowanej w kraju energii elektrycznej pochodziła będzie tylko i wyłącznie ze źródeł odnawialnych, gdzie oczywiście nadrzędną rolę odgrywać będzie fotowoltaika. Istotnie, zgodnie z ustaleniami, która zapadły swego czasu na szczeblu rządowym zdecydowana większość polskich elektrowni cieplnych opalanych węglem kamiennym bądź brunatnym ma przestać całkowicie istnieć już w przeciągu najbliższych kilkunastu lat.*

Autorzy artykułu podejmują próbę udzielenia odpowiedzi na pytanie, czy fotowoltaika będzie mogła w przyszłości zastąpić przeznaczone do likwidacji polskie elektrownie cieplne. Odpowiedź na tak postawione pytanie jest jednoznacznie negatywna i to nie tylko z powodu sezonowości produkcji energii elektrycznej w instalacjach fotowoltaicznej, ale przed wszystkim z powodu niemożności wprowadzenia do sieci elektroenergetycznych mocy rzędu dziesiątek gigawatów w szczycie jej produkcji w instalacjach fotowoltaicznych oraz niewykonalności koniecznego zbilansowania tak wielkich poziomów mocy w krajowym systemie elektroenergetycznym. Autorzy usiłują także udzielić odpowiedzi na pytanie, w jakim miejscu pod względem stopnia zaawansowania inwestycji w fotowoltaikę obecnie się znajdujemy i w związku z tym, ile mocy elektrycznej można w polskich elektrowniach fotowoltaicznych jeszcze dodatkowo zainstalować. Kolejną kwestią poruszoną przez autorów, jest próba oszacowania, jaki procent krajowego zapotrzebowania na energię elektryczną można maksymalnie pokryć z instalacji fotowoltaicznych, aby tego rodzaju postępowanie było jeszcze w jakikolwiek sposób uzasadnione ekonomicznie.

Słowa kluczowe: *elektroenergetyka, elektrownie cieplne, odnawialne źródła energii, fotowoltaika*

Introduction

Undoubtedly, the electric power engineering is not the most important and, simultaneously, the most neuralgic sector of the national economy. Without effectively functioning power energy, it is difficult to imagine functioning of anything in the contemporary world. Power system, as functioning in the reliable way, is absolutely necessary for functioning of the total national

industry, transport, trade, service, education, administration, defending system, financial sector and data centres. In general, it is necessary for common people to run normal life in the contemporary reality. Shortly speaking, power engineering is the most important issue!

In connection with the above facts, it seems to be evident that the introduction of any changes of fundamental nature in the domain neuralgic for functioning of the whole economy of the country and total social life must be first very deeply and thoroughly thought out and then, analysed in detail in all possible aspects. Committing any cardinal error as early as in the conception stage may result in the consequences of tragic character and, also, exert the catastrophic impact on the economy of the whole country; such consequences would be painfully sensible to the coming decades.

The stem of Polish electric energy system has been always constituted by black or brown-coal-fired power plants [5]. They are still responsible for the production of ca. ¾ of electric energy, produced in our country. At the same time, they are perceived as extremely reliable and exceptional stable sources of electric power as being almost completely insensitive to any caprices of the weather. In the coming years, it will be, however, subjected to radical changes because after several years, a decided majority of the functioning nowadays heat power plants is going to stop their work. On the other hand, their role will be undertaken, to a great extent, by renewable energy source from among which the photovoltaics is presently found at the first position.

Polish heat power plants

Table 1 contains basic information concerning nine greatest thermal power plants, being found at the territory of Poland. The power installed in each of the mentioned plants exceeds value of 1 GW.

From among the mentioned nine greatest thermal power plants, only two and based on the brown coal and in the remaining eight plants, the black coal is the basic type of fuel (additionally, in some of them, the boilers for burning of biomass have been installed but their meaning is rather marginal). When summing up the data found in Table 1, we may calculate that in the reasonable power plants there was installed total power accounting to 22.402 GW.

As it was earlier mentioned, the direction of the present energetic policy of the state assumes that at the beginning of the thirties of the 21th century, the mentioned above power plants will stop to exist at all – we are leaving carbon forever. By the way, it is worth noticing that in the countries such as China, India and numerous Asia countries, the trend is accurately opposite; besides it, the participation of the EU countries in the emission of CO_2 is only ca. 8% of its world emission what constitutes less than ca. 0.5% of its natural emission, connected mainly with the breathing processes of living organisms inhabiting our Globe.

Moreover, when investigating the public opinions of various home-grown or self-proclaimed "experts" in the field of electric energy power (they are most frequently the persons without any technical education) we may get the impression that the wide masses of our nation are convinced that such almost revolutionary energetic transformation will be pass without any pain and may only get much profit because we will possess cheap and pure electric current! So the advantage would be doubled! Why do we need these smoking carbon-based power plants, we will have completely pure (for the environment) photovoltaic at our disposal. By the way, the harmfulness of the total production connected with the manufacture of silicate monocrystals in relation to the environment is not mentioned at all (similarly as in the case of birds and bats which die after the "near meeting" with the rotating sales of windmills).

The impact of geographical latitude on profitability of photovoltaics

The profitability of photovoltaics is dependent first of all on the geographic latitude in which there were placed the semiconductor panels, transforming the energy of solar radiation into electric energy [1]. The most favourable conditions in this respect are found on the Earth's Equator. More we are going away from the equator towards one of the earth's poles, more the profitability of photovoltaics becomes decreased because of the seasonality of production; there are greater and greater discrepancies between the period spring-summer and

Table 1. The data concerning the greatest Polish heat power plants

Name	Year of launching	The installed power	Basic type of fueal	Operator
Bełchatów	1981	5,102 GW	Brown coal	PGE
Kozienice	1972	4,016 GW	Black coal	Enea
Opole	1988	3,342 GW	Black coal	PGE
Jaworzno	1979	2,255 GW	Black coal	Tauron
Połaniec	1979	1,882 GW	Black coal	Enea
Rybnik	1972	1,800 GW	Black coal	PGE
Turów	1962	1,488 GW	Brown coal	PGE
Dolna Odra	1974	1,362 GW	Black coal	PGE
Łaziska	1917	1,155 GW	Black coal	Tauron

analogical period autumn-winter. In the case of photovoltaic installations being found in the area between Tropic of Cancer and Tropic of Capricorn we may, in simplification, adopt that the considered production seasonality as a rule does not occur at all – in the discussed site the conditions for work of photovoltaic installations are optimal in this respect. When we, however begin to go away from the mentioned earth poles, the considered seasonality begins to play a more and more meaningful role.

The 50th parallel of the north latitude runs through the southern borders of Cracow. In connection with this fact, a greater part of our country is situated towards north from the mentioned 50th parallel. In the case of the installed photovoltaic panels at the mentioned site, it is difficult to speak about any optimal placement of these installations – in the contrary, the production seasonality there has a very big meaning. In effect, the photovoltaic installations, as being found as the territory of Poland work effectively only in the period of spring-summer where a day is relatively long and a night is short and the sun is suspended for a longer time relatively highly over the horizon. In turn, during the period of autumn-winter, production of electric energy from Polish photovoltaic installations is found, as a rule, on the symbolic level and the electric power plants of this type cannot have, especially in winter period, any significant meaning in the electric energy system.

In the connection with the above facts, we may adopt that value of mean annual indicator of utilization of the power, installed in the case of photovoltaic installations present ast the territory of Poland is equal to ca. 50% because they work effectively as rule for a half of the year. It is not the end, because in the case of photovoltaics – apart from the production seasonality – we have to deal with its daily cyclicality: the installations of this type function only when the sun is shining – in the night, the power generated by photovoltaic panels is equal exactly to zero watts. In connection with this fact, value of mean annual indicator of utilization of the power, installed in Polish photovoltaics panels must remain lowered down to 25%; they work, as a rule, only for a half of the year and moreover, for a half of 24h.

Unfortunately, the mean annual coefficient of utilization of the power installed in the photovoltaic system, as being analysed in practice, has a considerably lower value which does not exceed usually only 10%. Where does so big decline of the value of the considered coefficient come from?

First of all, it comes from the fact of installing the photovoltaic panels as immobile installations which at any rate do not follow the current situation of the sun on the sky. It causes that the angle of arranging the plane of the panels in relation to the spectrum of the bunch of solar radiuses is - for a greater part of their work – found at a very big distance from the value of optimal angle. It causes a considerable decline of the generated electric power. Additionally, the value of the generated power is also affected by cloudiness and, especially by atmospheric precipitation. In this case the decline of the generated power value may be even multiple and the photovoltaic panels covered with the snow, will not generate any electric power.

Final calculations should also consider such factors as decline of the efficiency of the process of transforming the light energy into electric energy, being caused by increased temperature of work of photovoltaic batteries what takes place especially in the summertime [1]. It is estimated that the increase in temperature of photovoltaic batteries by each Celsius centigrade above the nominal temperature of their work results in decline of the efficiency by ca. 0.3% and during the summer heats, photovoltaic panels may become heated up in a full sun shine even to more than 70oC; it results in decline of their efficiency value by as much as ca. 15%. The decline of the effectiveness of photovoltaic installations is also caused by the processes of ageing of the batteries. According to different estimates, the decrease in the effectiveness of work of the energy converting process may reach even to 1% per each successive year of the work of batteries. Therefore, after twenty, or thirty years of utilization of photovoltaic panels, it is not a small value. We cannot also forget about the losses of energy in the inverter which occur during the conversion of the direct current (DC), received directly from the photovoltaic batteries, into alternating current (AC), being sent to the electrical network [7].

As it was already mentioned, in the case of installing the photovoltaic panels in the geographical latitudes typical of our country and after having considered of the discussed above factors, we should not be surprised that value of the mean annual indicator of utilization of the installed power is only ca. 10%. Meanwhile, in the inter-tropical zone, the discussed value is twice higher due to the lack of occurrence of the considered effect fo seasonality of electric energy production. Additionally, when taking the more favourable conditions of solar radiation into account (sun passes there above the horizon considerably higher) and the lower number of cloudy days during the year, the coefficient of utilization of the installed power may reach value even above 30%; therefore, it is significantly more profitable under such conditions [1].

Perspectives for development of photovoltaic installations

The direct consequence of utilization of only 10% of the installed power, in average, in Polish photovoltaics is the fact that in order to replace the heat power plant with power of 1 GW (in respect of annual electric energy production) we should install photovoltaic panels with total power of 10 GW. During the yare of elaborating the present paper, the power installed in Polish photovoltaics should reach value of ca. 15 GW. It is accurately as much as it may be produced by average-size heat power plant with power of 1.5 GM during a year. Meanwhile, the further dynamic increase in the power installed in Polish photovoltaic panels is anticipated what may be supported by Figure 1.

As it results from Table 1, in the perspective of few coming years, the power installed in Polish photovoltaics should be doubled, reaching to value of 30 GW. Unfortunately, it is not sufficient for to replace the greatest brown coal-fired power Polish plant in Bełchatów with the power of more than 5 GW [2]. To obtain such target, it should be necessary to install more than

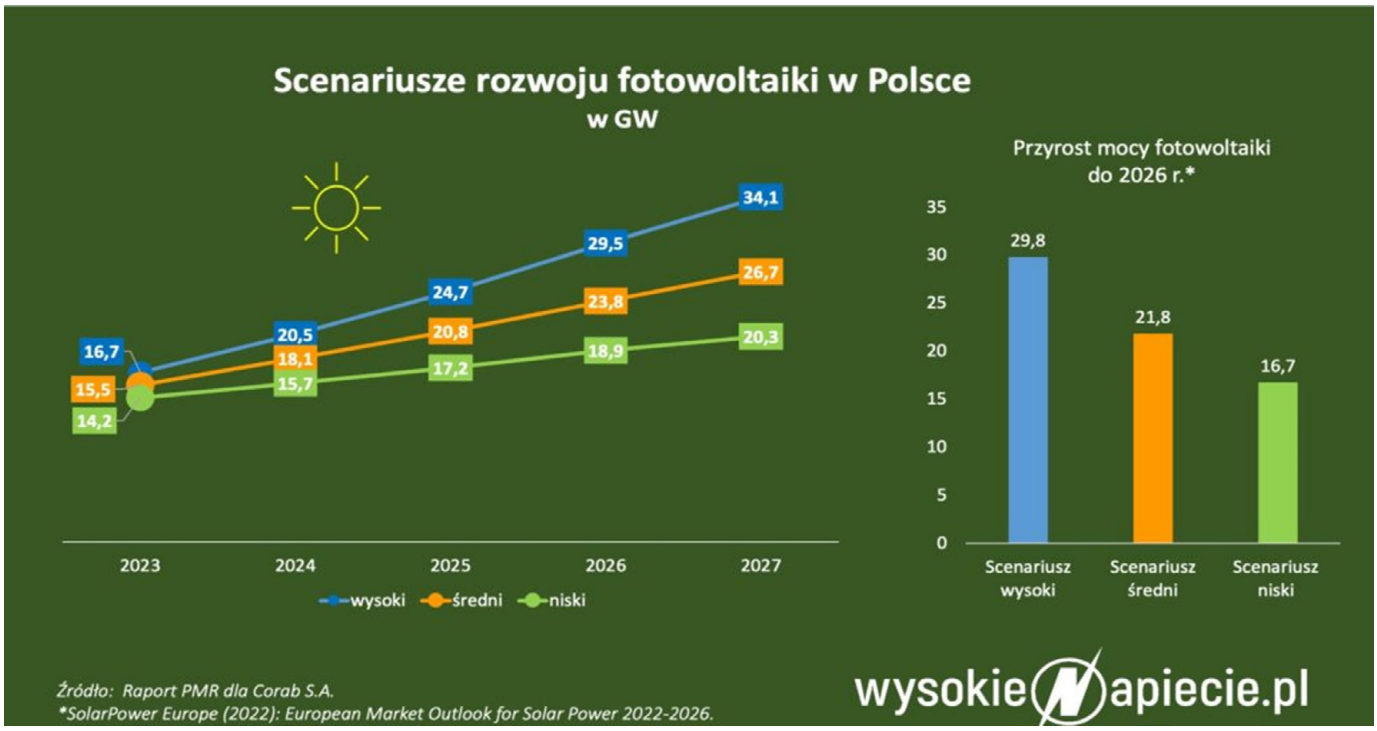

Fig. 1. Different prognoses of the increase of power, installed in Polish photovoltaics (source: https://wysokienapiecie/pl/83071-fotowoltaika-dla-firm-coraz-wazniejsza

50 GW f power in Polish photovoltaics. On the other hand, when we look at diagram, presented in Tab.1, we may expect that the mentioned level will be reached in the successive coming years because the analysed diagram seems to go constantly upwards and, what is more important, any signs of flattening are not visible.

In turn, the replacement of electric energy production coming from all mentioned greatest Polish power plants with the photovoltaic installations would require installing the total power at the level of 220 GW (to this end, *nota bene*, it would be enough to cover the roofs of the half of buildings at the territory of Poland).

Let assume, purely hypothetically that it will be possible in the future to build photovoltaic power plants with the mentioned above power, i.e. more than 200 GW. In such situation, in May, June and July at the peak of production, occurring at the 13th hour of the day (we consider, of course, summer time) photovoltaic should generate at least 100 GW of electric power in total.

We do not need convince – I hope – anybody that at the present technical state in which the national electric energy transmission networks are found, the introduction of power of the order of 100 GW is not possible at all [8]. To this purpose, it should be necessary to build ca. 50 new two-route lines, working under the tension of 400 kV. It would be the investment of almost unimaginable scale. It is enough to say that there is now considered the construction of electric energy transmitting line of direct current (DC) joining the coast of the Baltic sea and the Upper Silesia district as to send the power, generated in the wind power plants installed at the sea. The planned course of the considered line of direct current is given in Figure 2. It is expected to work under the constant tension of at least 500 kV and the implementation of the total project would last for at least ten years and cost many billions PLN. Meanwhile, the maximum transmitting ability of the considered line is to be

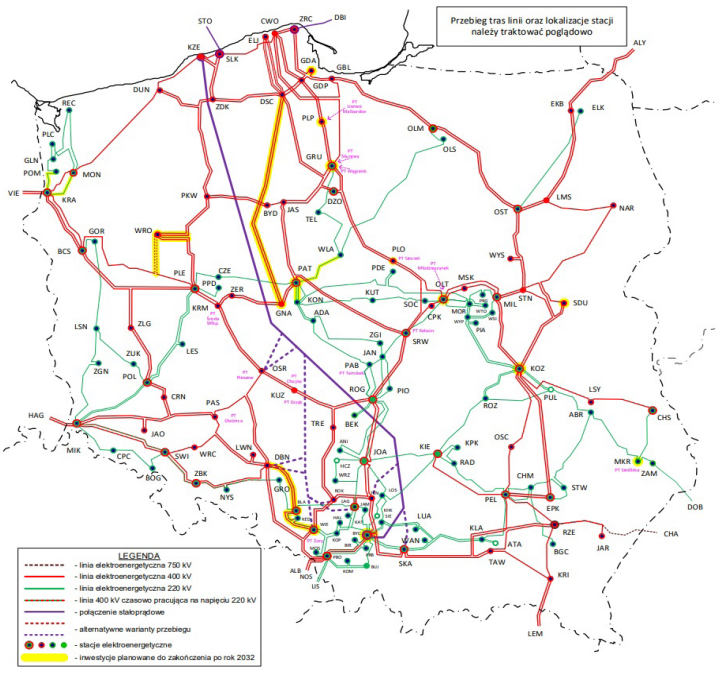

Fig. 2. Map, showing the course of the planned transmitting line of direct current, running from the vicinities of Ustka to the area of the Upper Silesia district (Source: https://swiatoze.pl/autostrada-energetyczna-polaczy-oze-na-polnocy-z-przemyslem-na-poludniu-polski-za-10 lat/)

about 4 GW what would be insignificant value as compared to the considered hypothetic 100 GW of electric power deriving from photovoltaic electric plants.

A brief analysis of Figure 2 shows that Poland has a relatively small number of electric energy transmitting lines of the highest tensions (220 and 400 kV) [4]. Moreover, many of the connections, illustrated in Figure 2, implemented under the tension of 400 kV is now found only in the stage of investment or only preliminary project.

Let's assume, purely hypothetically that in the coming years we would be able to implement the investments in electric energy transmitting lines what would facilitate introduction to them, at the peak moment, the huge powers at the level of 100 GM coming from photovoltaics. Then, we would meet the more serious problem: what we should do with such a gigantic value of the additional power? During the summer months, the demand on electric energy in Poland does not usually exceed (in the noon hours) value of 20 GM in working days and in weekends is it considerably lower. Assuming again the hypothetical situation that the whole demand on the power in the discussed period is covered only and exclusively from the photovoltaic installations (the question may be asked at this moment: so what about the wind plants and water flowing plants?) we will have the unimaginable excess of power of order about 80 GW.

How to store the energy generated in photovoltaic installations?

The first conception coming to my mind is to export the mentioned surplus to the neighbouring countries and perhaps earn on it quite well. Unfortunately, in practice, it is not so simple. In Figure 3 there are given the data made available at the Internet page of polish Electric Energy networks S.A. (PSE) on June, 4, 2023 for 14th hour of the day and night period.

DEMAND [MW]	**15 688**
GENERATION [MW]	**16 256**
Heat power plants	7 481
Water power plants	163
Wind power plants	151
Photovoltaic installations	8 460
Other renewable energy plants	0
BALANCE OF TOTAL EXCHANGE [MW]	**592 EXPORT**
FREQUENCY [Hz]	**49,993**

Fig. 3. Data concerning powers generated in the national electric energy system on June, 4, 2023 (Source: https://pse.pl/home)

As it is followed from Figure 3, during the analysed period of time, the photovoltaic power plants introduced power equal to 8.460 GM to the electric energy system, at the total demand of 15.688 GW (it was Sunday what resulted in a relatively low demand on energy). It is worth noting that at the same time, the power of heat power plants was lowered to only 7.481 GW what constitutes their technical minimum and perhaps a part of the remaining electric energy blocs was shifted to the so-called hot reserve (unfortunately, the data of such type are not published by BSE; it's a pity because it would give a more readable image of the total situation in the Polish power market). It is worthy paying attention to the fact that water flow power plants produced then small energy amount i.e. 163 MW (what is rather typical value) and wind power plants generated 151 MW (the wind was then very rare). If the wind had been strong at the discussed period, the considered power surplus in the system would have exceeded even 90 GW. In Polish wind power plants there are installed more than 9 GM of power in total and the successive investments are planned, including those ones at the area of the Baltic Sea where the velocities of wind are statistically higher.

To get familiarized with the possibilities of electric energy export to the neighbouring countries we may look at Fig.4 where the data published by PSE on the cross-border exchange of power on June 4, 2023 in the 14th hour of day and night period have been presented.

As it results from Figure 4, the power of value of 1.424 GW is introduced to the national electric energy system by two two-route transmitting lines under the tension of 400 kV from the territory of Germany. Then, the discussed electric power is transferred further *via* the territory of Poland and finally it is exported to the neighbouring countries such as Sweden (connection by permanent current cable under the bottom of the Baltic Sea), Lithuania, the Czech Republic, Slovakia and Ukraine.

On the other side, it should be admitted that during the analysed period of time, as it results from Figure 3, we exported to the neighbouring countries 592 MW of electric power in total. It is not especially impressive value; at any rate it does not solve the problem how to get rid of the hypothetic surplus of 80 GW of the power generated from the photovoltaic installations.

Export of energy, produced in photovoltaic power plants is not possible due to the fact that our west neighbour in the past invested very much in the development of photovoltaic installations and the total power of the power plants of such type has exceeded the level of 60 GW in Germany during the moment of writing the present paper; the new successive installations of this type are also constantly developed. Our south neighbours (the Czech people and Slovakians) invest also much in photovoltaics. The conditions for power generation from photovoltaic batteries are somewhat more favourable in these countries as compared to Poland (they are situated somewhat nearer to Equator). Therefore, we will be never able to export the surplus of the energy, generated in photovoltaic system to the mentioned above countries as they will have the same problem: what to do with the excessive gigawatts coming from the photovoltaic installations? The serious problems appear at

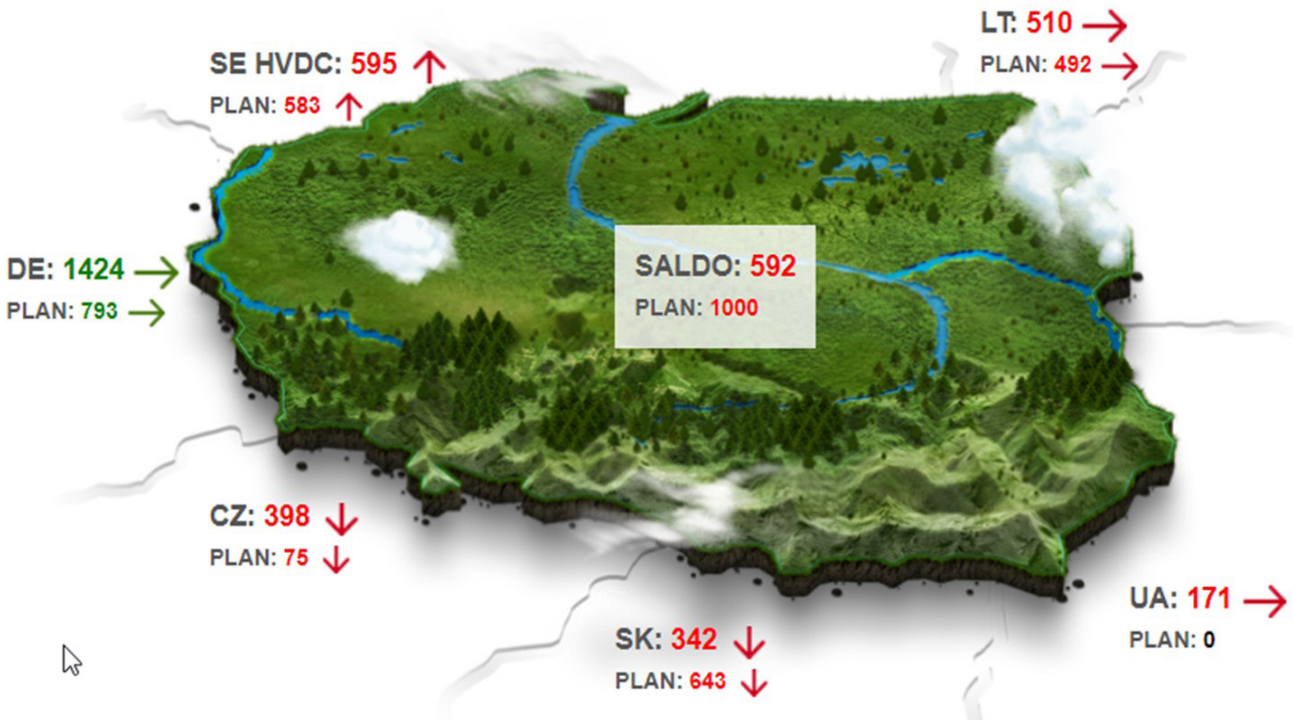

Fig. 4. The data concerning the cross-border exchange of power on June, 4, 2023 (Source: https://pse.pl/home)

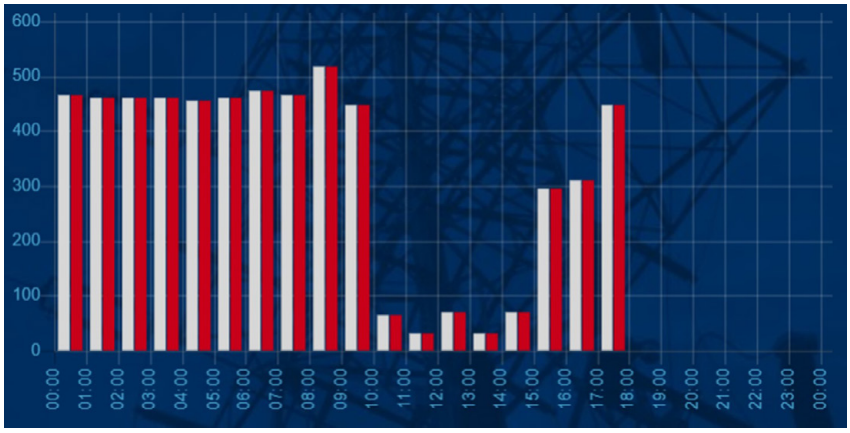

Fig. 5. Information on the gross prices of electric energy in the particular hours of 24h period, on May, 9, 2023 (Source: https://pse.pl/home)

present under the situation when during the peak moment of power generation coming from photovoltaics, the strong winds appear. Such situation occurred, *inter alia*, on May, 9, 2023. Figure 5. illustrates the data, published by PSE concerning the gross prices of energy in the particular hours of day and night period.

As it is followed from Figure 5, in the noon hours, i.e. during the peak of generation of energy from photovoltaic sources, the gross prices of electric energy dropped dramatically to the vicinities of zero (even to ca. 20 PLN per one megawatt hour). At the discussed time, the stability of work of electric power system was rescued by the extraordinary export of electric energy to our south neighbours. In practice, it was, however, giving them the energy produced in the national sources substantially as priceless.

It is worth to take a look at the situation during the so-called evening peak of loading. When dusk falls, all people switch the lights on, the street lamps become also switched and on connection with these facts, the demand on the power in the electric energy system is relatively highest. In Figure 6, there are given the data published at the Internet page of PSE on 6, June, 2023 for the 21st hour of the day and night period.

DEMAND [MW]	**19 602**
GENERATION [MW]	**17 035**
Heat power plants	14 802
Water power plants	1 050
Wind power plants	1 183
Photovoltaic installations	0
Other renewable energy plants	0
BALANCE OF TOTAL EXCHANGE [MW]	**2 529 IMPORT**
FREQUENCY [Hz]	**49,988**

Fig. 6. The data concerning the power generated in the national electric energy system on 6, June, 2023 (Source: https://pse.pl/home)

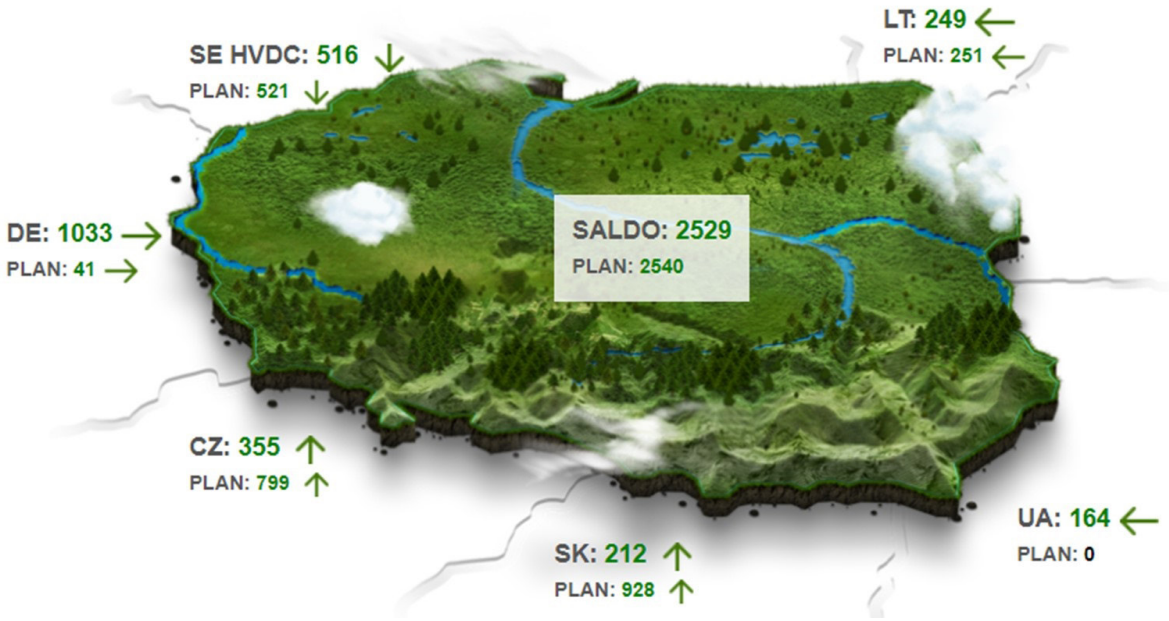

Fig. 7. The data concerning the cross-border exchange of power on June, 6, 2023 (Source: https://pse.pl/home)

As it is followed from Figure 6, in the analysed period of time, the demand on power in the national electric energy system amounted to 19,602 GW, including 14.802 GW from the heat power plants. Additionally, in the discussed period of time, wind power plants generated 1.183 GW and water power plants made the contribution of 1.050 GW. We should however mention that the recent of the discussed categories includes also pumped-storage power plants which only store (efficiency of ca. 70%) the previously produced electric energy being generated mainly in heat power plants; therefore, their classification in the category of renewable energy sources is rather questionable. From Figure 6, it is followed also that during the mentioned period of evening peak, the photovoltaic plants generated strictly zero watts and moreover we were forced to considerable import of electric energy from the neighbouring countries in amount of 2.529 GW at rather high price. The detailed data of the structure of the considered import of electric energy from the neighbouring countries have been presented in Figure 7.

As it is followed from Figure 7, during the evening peaks of energy loading, we are forced to buy, most probably at high prices, the electric energy from each of our neighbours with whom we have the active cross-border connection. The greatest import is implemented from Germany (1033 MW) and, also from Sweden (516 MW).

When coming back to the problem of disposing the hypothetic 80 GW of power generated by photovoltaic sources, the next idea refers, of course, to the storage of the surplus of the produced energy and then, its recovery with the appropriate efficiency during the evening peak of loading and at night. To these ends, the storage-pumped power plants consisting of two reservoirs (lower and upper) are employed. Water is pumped between these two reservoirs, transforming the electric energy into potential energy of water mass.

The greatest storage-pumped power plant in the world is found at present in China (Fig. 8). It reaches the power of 3.6 GW and, besides it what is more important, facilitates the storage of as much as ca. 40 GWh of electric energy. It may, therefore, work with its full power for the period of more than 10 hours.

Fig. 8. View of the greatest storage-pumped power plant in China (Source: https://swiatoze.pl/elektrownia-szczytowo-pompowa-o-najwiekszej-mocy-zainstalowanej-na-swiecie-juz-dziala-w-chinach/)

As compared to the discussed China giant, Polish storage-pumped power plants are very small. We have 6 objects of such type at our disposal; they are characterized by the following values of the generated power:

- Żarnowiec – 716 MW;
- Porąbka-Zar – 500 MW;
- Solina – 200 MW;
- Żydowo – 167 MW;
- Czorsztyn- Niedzica- Sromowce Wyżne – 94 MW;
- Dychów – 90 MW.

When working in the pumping mode, the Polish storage-pumped power plants collect maximum power of 2 GW from

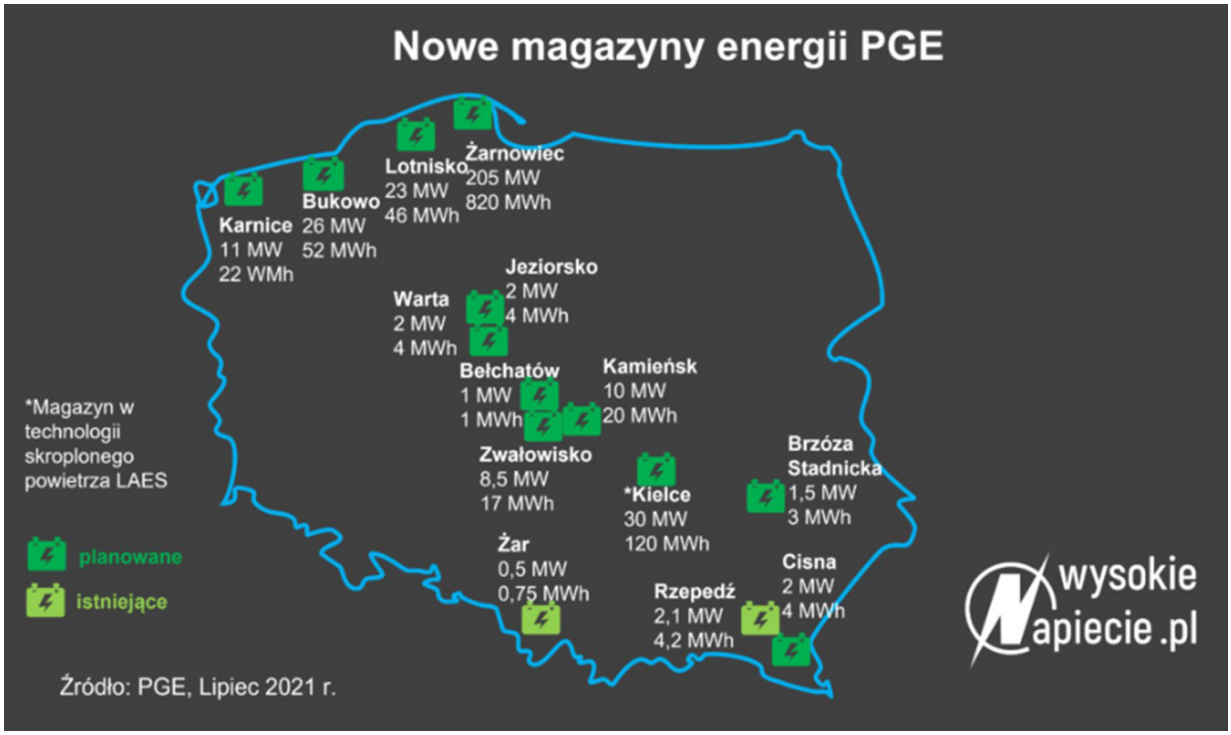

Fig. 9. The distribution of the existing and planned battery storehouses of energy in Poland (Source: https://wysokienaoiecie.pl/84360-magazyny-energii-sa-niezbedne/)

the electric energy system. With the assuming that their upper reservoirs have been previously completely empties, they are able to pump water for the period of maximum 4 hours, collecting the energy equal to 8 GW for this purpose. Meanwhile the management of the surplus of power generated by photovoltaic system in the hypothetically considered amount of 80 GW for the period of, let's say 10 hours per 24h period, it would require the storage of energy in the quantity of 800 GWh. It means that to this end, we should have hundred times more storage-pumped power plants with the same parameters as we have now. It is highly doubtful whether it would be possible to find the sites for their construction at the whole territory of Poland, not mentioning the astronomic costs of such investments [3].

Processing of electric energy in chemical energy, accumulated in batteries is another method for the storage of electric energy. The first installations of such type have been already erected in Poland; the successive ones are planned, as well. Their location has been presented in Figure 9.

If we look, however, more precisely at Figure 9, it may be seen that the question of utilization of battery energy storehouses is not so optimistic as if it could seem at the very beginning. From among the installations, submitted in Figure 9, only one (Żarnowiec) may be recognized as relatively grater as its power is equal to 205 MW and it enables accumulation of electric energy for the period of ca. 4 hours. The remaining battery energy storehouses are the installations nearly microscopic, with power of only few, several or several hundred megawatts; they are able to accumulate energy for the period of around two hours. From the viewpoint of storage of electric energy surplus, generated in photovoltaic system, the battery storehouses do not have any significant meaning.

How much power more may be installed in Polish photovoltaic system?

When I was writing the present paper, the power installed in photovoltaic installations in Poland reached value of 14 GW. At this moment, we may automatically ask the following question: how much more power may be installed with the following effect:

1) its transmission by the existing electric energy network is technically feasible;
2) the energy produced in the mentioned installation is fully utilized.

What is the use of such amount if having even 40 GW installed in photovoltaic panels (that is, almost three times more than now) we will be not able to obtain a half of the generated power in the peak production moment at any rate [2]. Under such situation, it will be necessary to disconnect compulsorily the selected photovoltaic farms from the network in order to ensure the balance of the power in the electric energy system. But just such procedure causes a drastic decline of value of the indicator of mean annual utilization of the power, installed in photovoltaic system which in the assumed case of the total utilization of energy generated in the panels at the territory of Poland is equal to only ca. 10%. If, however it is not possible to obtain a half of the energy at the peak of the photovoltaic generation, value of the mentioned coefficient will fall below only 5%. In such case, the question about any profitability of the voltaic system of this type will be only a kind of rhetoric question.

Figure 10 contains the data published by PSE on April, 22, 2023 in the thirteenth hour of 24h period.

During the considered period of time, the demand on the power in electric energy system amounted to 18.276 GW;

DEMAND [MW]	**18 276**
GENERATION [MW]	**18 044**
Heat power plants	10 009
Water power plants	328
Wind power plants	53
Photovoltaic installations	7 652
Other renewable energy plants	0
BALANCE OF TOTAL EXCHANGE [MW]	**202 IMPORT**
FREQUENCY [Hz]	**50,055**

Fig. 10. The data concerning the powers in the national electric energy system on 22, April, 2023-07-31(Source: https://pse.pl/home)

voltaic generated 7.652 GW and the remaining renewable energy sources gave only 0.381 GW. As usual, heat power plants generated as much as 10.009 GW. The minimal total power at which the national heat power plants may function is equal to ca. 7 GW. The mentioned power plants cannot be, however, completely disconnected due to the fact that when the dusk is commenced, they will be very necessary (simply indispensable) and they will have to increase the generated power considerably as to cover the increasing demand on energy during the evening peak of load.

As it is followed from Figure 10, the heat power plants work with the total power amounting to ca. 10 GW, so there is a certain reserve which could be employed in potential reduction of the power by ca. 3 GW. At the same time, it is worth mentioning that in the discussed day, there was a very weak wind and in connection with this fact, wind power plants generated only 53 MW, most of the windmills did not rotate at all. Meanwhile, as it is followed from Figure 6, Polish windmills generate typically the total power of the order of 1 GW. Simultaneously, as it results from Figure 10, in the discussed ay there was import of electric power in amount of 202 MW; therefore, at the situation of stronger winds, the mentioned import would not occur at all; instead, we could even expect a small export of energy. Reassuming, we may say (with a certain simplification) that the power generated by photovoltaic system would be subjected to decrease to ca. 7 GW what is the absolute minimum in the case of the national electric energy system. As the total power installed in Polish storage-pumped power plants equals to ca. 2 GW, we may assume as follows: if all considered energy plants had pumped water with their full power during the peak of the power generation from photovoltaic system, the photovoltaic plants could deliver the power higher by ca. 2 GW.

It remains, however, debatable question: to what level the upper reservoirs of the mentioned above plants may be emptied because they must constitute always a considerable reserve of the so-called intervention power, having a crucial meaning from the viewpoint of safety of work of electric energy system; sometimes it is the last resort before occurrence of catastrophe in a form of the universal *blackout*. The upper reservoirs of storage-pumped power plants cannot be emptied totally, to zero, what – in practice – limits considerably the time for which the water may be pumped until their complete filling.

Reassuming, after consideration of the admitted reduction of power of heat power plants and the possibilities of the additional work of storage-pumped power plants, connected with the pumping of water to the upper reservoirs, we may assume that the power generated by photovoltaic system could be still by ca. 5 GW higher. It is followed from Figure 10 that Polish photovoltaic power plants in the peak period deliver about 7.5 GW of power, with the total installed power equal to ca 14 GW. Therefore, theoretically, the mentioned installations could generate still 5 GW more; it would be ca 12.5 GW in total. Meanwhile, the prognoses for the coming few years anticipate doubling of the power installed in Polish photovoltaic up to value of ca. 28 GW. Such situation will cause that during the peak of generation, the discussed power plants will deliver about 15 GW in total, i.e. by 2.5 GW more than the calculated previously value of 12.5 GW. Perhaps it would be possible to export the mentioned additional 2.5 GW to the neighbouring countries (probably at a very low price, perhaps even of negative value) but it can be clearly seen that the value of power installed in Polish photovoltaic at the level of ca. 25 GW is principally the limit value, the exceeding of which has not any sense; it would result in compulsory switching on of photovoltaic installations during the period of peak power generation. Meanwhile when looking at Figure 1, we may conclude that the ambitions concerning the development of Polish photovoltaic system go considerably further, ignoring completely the elementary economic calculus and analysis of profitability of further development of the discussed sector of electric power system.

How much energy coming from photovoltaic may be produced in Poland?

Let's try to answer the following question: how high percentage (maximum) of electric energy produced in Poland during one year may come from photovoltaics system when assuming that the whole energy generated in Photovoltaics panels would be completely utilized. Table 2 contains the data concerning generation of energy from photovoltaic sources on 12, June, 2023.

As it is followed from Table 2, the highest value of the power, generated from the photovoltaic sources had place at the 14th hour of the 24h period and was equal to 7.565 GM, in average. In order to simplify the further considerations, let's assume that the demand on electric energy in Poland is constant and amounts strictly to 20 GW at each hour of the day-and-night period during the whole year. To cover fully the demand of the customers,

Table 2. The data concerning generation of power from photovoltaic sources in the particular hours of 24h period on June, 12, 2023 (Source: https://pse.pl/home)

Hour of 24h period	Power generated from photovoltaic sources [GW]
1	0
2	0
3	0
4	0
5	0.067
6	0.442
7	1.437
8	3.284
9	5.320
10	6.637
11	6.914
12	7.400
13	7.534
14	7.565
15	7.374
16	6.580
17	5.226
18	3.695
19	2.079
20	0.849
21	0.274

480 GW should be produced during 24 h period; during the whole year, it would be necessary to generate 175.2 TWh of electric energy. Let's assume – purely theoretically – that we do not have at all any coal-fired power plants in Poland, only gas turbines, so we cannot be flexibly adjusted to the current performance of photovoltaic installations in respect of the generated power. It follows that in the 14th hour of the day photovoltaic system should supply power in amount of ca 20 GW and, in connection with this fact, cover totally the demand of the users. During the remaining hours of 24-h period, gas turbines must additionally perform their work because the power supplied by photovoltaic system will be, unfortunately, lower than the required 20 GW.

At the present level of power installed in photovoltaic system amounting to 14 GW at the peak of production in the 14th hour of the day, the mentioned panels generate 7.565 GW of electric power in total, so the increase of the level of generated power up to 20 G would require the increase of the installed power by 264 times (up to the level of ca. 37 GW). Then, the values contained in Table 2 should be also multiplied by coefficient 2,.64. It would allow determining the amount of energy produced by photovoltaic system in the particular hours of day-and-night period.

The considered values are as follows:

- hour 5 - 0.177 GWh,
- hour 6 - 1.167 GWh,
- hour 7 - 3.794 GWh,
- hour 8 - 8.670 GWh,
- hour 9 - 14.045 GWh,
- hour 10 - 17.522 GWh,
- hour 11 - 18.253 GWh,
- hour 12 - 19.536 GWh,
- hour 13 - 19.890 GWh,
- hour 14 - 19.972 GWh,
- hour 15 - 19.467 GWh,
- hour 16 - 17.371 GWh,
- hour 17 - 13.770 GWh,
- hour 18 - 9.755 GWh,
- hour 19 - 5.489 GWh,
- hour 20 - 2.241 GWh,
- hour 21 - 0.723 GWh,
- hour 22 - 0.063 GWh.

In total, photovoltaic system would produce 191.9 GWh of electric energy during the day and night period (24 h). Let's assume again, in order to simplify the conducted considerations that photovoltaic system works with the indicated above hourly values of power for the period of a half of the year i.e. after rounding for 182 days (it is of course, a very optimistic scenario). In such situation, all Polish photovoltaic installations would produce 34.9 TWh of electric energy during the year what would constitute 19.9% of the whole electric energy produced in Poland during the year.

During the conducted calculations, the possibilities of storing the energy in storage-pumped power plants were not taken into account. The number of such installations in Poland is relatively small, so their consideration would not change much. On the other hand, generation of power from other renewable sources, especially from windmills and water power plants were not taken into account; it compensates, to a certain extent, the effect connected with the lack of consideration of the possibilities of storing the energy.

As it is followed from the presented calculations, geographic latitude typical of the location of our country does not allow generating by the photovoltaic system more than ca. 20% of the total energy produced in Poland. Moreover, the mentioned result was achieved with very optimistic assumptions: the produced photovoltaic energy will be always utilized in 100%. Such solution would, however, make the cooperation of photovoltaics with the coal-fired heat power plants impossible, and especially with nuclear energetics. On the other hand, it would be potentially possible to occur in the case of application of gas turbines. It is rather completely excluded at the present geopolitical situation, not mentioning the threat of a serious danger to the safety of our energetic system [6].

Therefore, when looking at the whole problem from the realistic viewpoint, we should univocally state that we are able to produce from photovoltaics perhaps ca. 10% of the total electric energy generated in Poland. In the case of building many

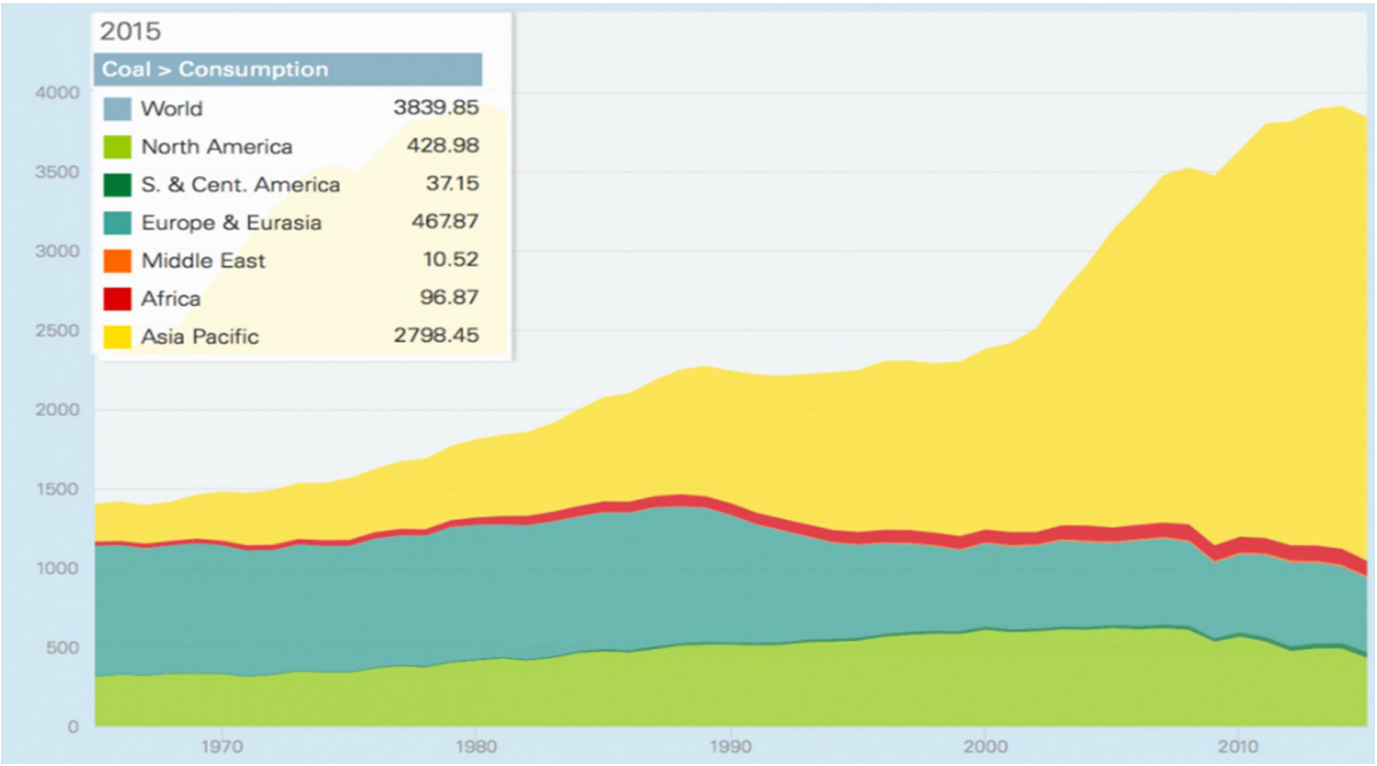

Fig. 11. Diagram, illustrating the increase ibn coal consumption all over the world during the recent few decades (Source: https://independenttardes.pl/swiatelko-w-tunelu-dla-wegla.html)

pumped-storage power plants it may amount to few percent more, let's say within the limits of 15%. The question arises: is it worth to bear enormous costs (many billions PLN) connected with the erection of successive pumped-storage power plants what would undoubtedly cause the furious reaction of ecologists and wide social protests of the people, displaced from the areas intended for construction of water reservoirs.

The analogical question may be asked even in the context of the mentioned 10% of electric energy which may be annually gained from photovoltaic system in Poland in the case of its cooperation with heat power plants or future nuclear power plants. Whether the discussed 10% only of the total electric energy produced in Poland is worth bearing the so-far and future enormous costs of all those governmental programmes and nearly gigantic subsidies for the prosuments? What may the discussed fact change in a final calculation when Poland is, anyway, responsible for less than 1% of the world emission of CO_2? If we even will contribute to the fact that the world emission

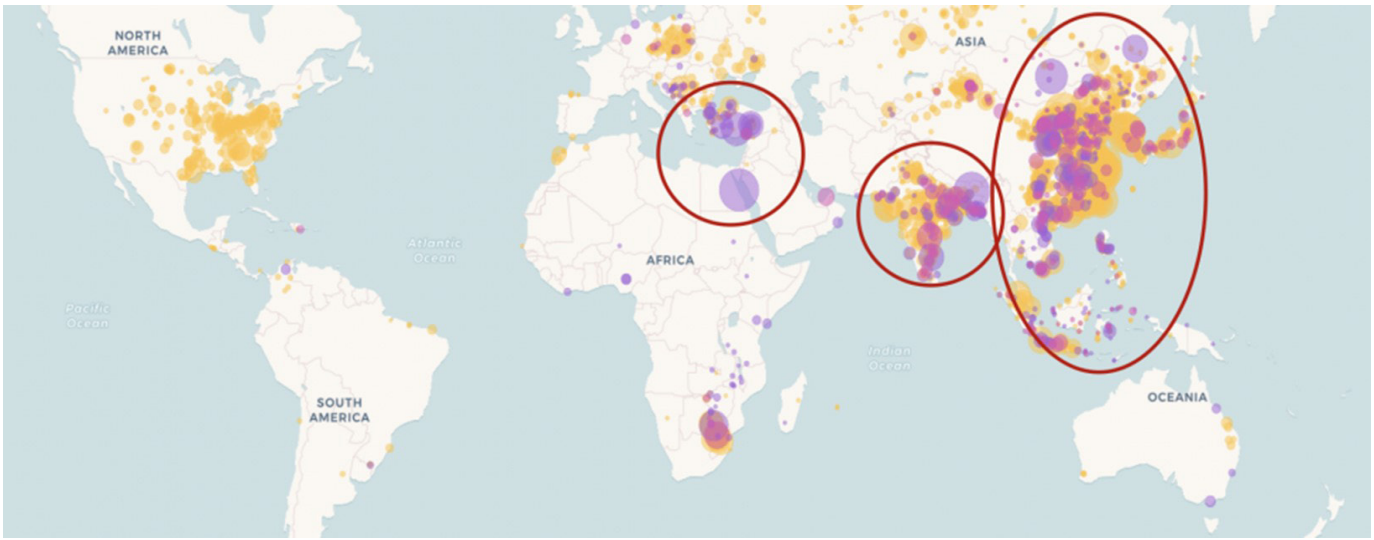

Fig. 12. Geographic distribution of functioning, being constructed and being planned coal mines (Source: https://independenttrade.pl/w-jakie-surowce-warto-inwestowac.html)

of carbon dioxide is decreased by one per mille owing to Polish photovoltaic system, it will be "compensated" with the surplus by many Asia countries which are not worried with such limitations and do not have any intentions to introduce them in this respect. To be convinced of this, it is enough to analyse the diagram, presented in Figure 11. It is distinctly clear that relatively small decline in carbon consumption in Europe and the North America is systematically compensated with a quite great surplus in Asian countries where coal mining is constantly increasing.

It is also worth to get familiarized with the map, presented in Figure 12, where yellow colour means the existing now coal mines whereas the new launched mines and those ones in the course of building or those only planned are marked with darker colours. As is can be seen (Fig. 12), the world does not give up the coal at all – in the contrary, there are planned gigantic investments connected with building of many new mines. We may distinguish here especially three areas: region of the Near East, area of India and region of China and South-East Asia. The construction of new coal mines is also planned in the South Africa and in Australia.

Summing up

With each second, the enormous quantities of radiant energy coming directly from the Sun, arrives to the surface of the Earth. Apparently, it seems that its utilization and effective management could contribute for always to the definitive solution of all energetic problems of humanity. Unfortunately, in practice, overcoming of the natural forces and employment them in work with the aim to satisfy the energetic needs of our technical civilisation is not as simple as it could seem at the first sight.

Photovoltaics may constitute a certain additional source of energy, the utilization of which in reasonable limits may be economically justified. Nevertheless, photovoltaics will never be the fundamental source of electric energy and definitely it will not enable the complete elimination of heat power plants. Moreover, only the power plants equipped with gas turbines are suitable for the most effective cooperation with photovoltaics; they may be quickly detached and then, again started up as quickly as during several dozen minutes (for comparison, re-ignition of the coal bloc takes even 8 hours). The transformation of the national electric energy system into gas fuel seems nowadays highly problematic – it would be difficult – at the existing transmission difficulties – to ensure the quantities of fuel for gas power plants, not mentioning even the energetic safety of such undertaking (almost complete dependence on the unstable foreign deliveries).

On the other hand, nuclear power plants are not suitable for cooperation with photovoltaic at all, as in such case there are no practical possibilities of regulating their power in a 24g period cycle (not mentioning their periodical switching out from work). Simply speaking, nuclear reactor must work all the time with its nominal power and any changes of it are a very slow and highly undesirable process (increase of the risk of failure). It generates the next question: the justification of constructing many nuclear power plants in Poland in the coming ten years (three bigger and a considerable number of small modular reactors) at the situation when we so strongly bet on development of photovoltaic installations. It seems that there is a distinct contradiction between the discussed two types of electric energy sources which will be difficult to make reconciled in the future [6].

Finally, it is worth mentioning that photovoltaic system is not the only one known method for conversion of solar radiation energy into electric energy. There have been already constructed experimental installations, composed of many thousands of mirrors, focusing rays of sunlight in a relatively small area as to heat up a liquid in a closed system to a very high temperature (for example, liquid sodium or brine). Then, the mentioned liquid is used for production of water vapour, driving the turbine connected with the current generator [5]. In such case, naturally stored energy of sun radiation is converted into heat energy of the liquid, heated up to a very high temperature.

We cannot also forget about "natural" photovoltaics that is, about green plants which replace the energy of solar radiation into biomass [1]. It is also the effective method for energy storage as the biomass in a dry state may be as a rule stored for any time; then, it may be burned in order to transform it into electric energy at the moment when there is the greatest demand on it.

Perhaps the discussed above problems are the appropriate directions of the studies on the effective utilization of the Sun energy, coming to our Globe whereas, at present, we speak practically and exclusively about photovoltaics.

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RELIABILITY OF PRINTERS 3DCP DURING CONTINUOUS WORK

NIEZAWODNOŚĆ DRUKAREK 3DCP W TRAKCIE CIĄGŁEJ PRACY

Summary: *The paper presents the studies on the reliability of printer Rebuild v3 during the implementation of the order of the Institute of Construction Technology. The object of the study was printing out of three miniature houses for fire tests and evaluation of burning ability of printouts made from the concrete. All the houses were printed during one session, lasting for 27h. Apart from the process of producing the objects, it was also possible to check the reliability and behaviour of the printer in so long and non-interrupted process.*

Keywords: *printer 3DPC, printer Rebuild v3, construction, reliability test*

Streszczenie: *Artykuł przedstawia badania niezawodności drukarki REbuild v3 w trakcie realizacji zlecenia dla Instytutu Techniki Budowlanej. Przedmiotem badania było wydrukowanie trzech miniaturowych domków do testów ogniowych i oceny palności wydruków z betonu. Wszystkie domki zostały wydrukowane podczas jednej sesji trwającej 27 godzin. Poza samym procesem wykonania obiektów, udało się sprawdzić niezawodność i zachowanie drukarki w tak długim i nieprzerywanym procesie.*

Słowa kluczowe: *drukarka 3DCP, drukarka REbuild v3, budownictwo, badanie niezawodności*

Introduction

At present, construction is the greatest sector of the industry which has not been automated. It is connected with many negative social consequences such as the highest mortality rate as compared to all remaining branches of the economy [1] and also, the economic effects among which the deficit of qualified physical workers is the most significant phenomenon [2, 3 4]. Therefore, it is estimated that value of 3DCP market will be very quickly increasing [5, 6]. Print 3 D may be employed in the target site as well as in the manufacturing hall for performance of ready-to-install prefabricates.

The aim of the work

IThe reliability tests were conducted during the implementation of the work, ordered by the Institute of Construction Technology. The purpose was to print three miniature houses for fire tests and evaluation of burning ability of printouts made from concrete. The mentioned houses had the external dimensions equal to 2.4 m x 3.4 m x 2.2 m (illustration with the dimension is given below). Each of them was placed on a separate, prefabricated plate made from reinforced concrete with the dimensions 2.5 m x 3.5 m x 0.2 m and weight of 4 tons each. All the houses were printed during one session lasting for 27 hours. Apart from the process of printing the objects, it was also possible to check the reliability and behaviour of the printer during such long and non-interrupted process. For printing, the printer Rebuild v3 was used.

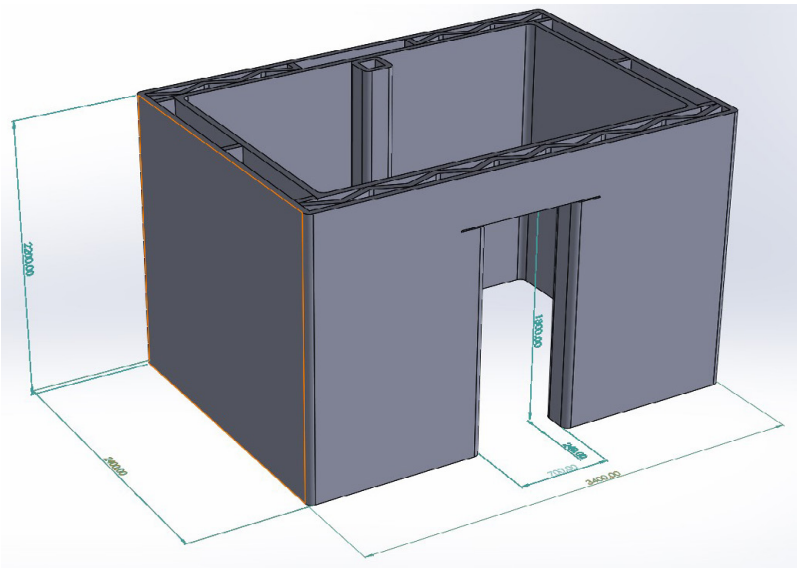

Fig. 1. Dimensions of the object: 2.4m x 3.4 m x 2.2 m

Fig. 2. Printer Rebuild v3. Real view from the first building site of this type in Poland, with the application of concrete in 3D printing

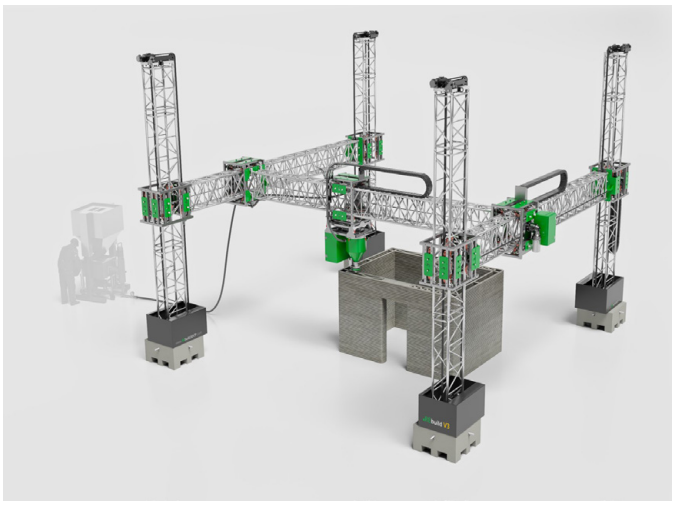

Fig. 3. Computer model of printer

Fig. 4. Printing of houses (reinforcement and thermocouples are visible)

During printing, thermocouples were inserted between the selected layers for temperature measurements. In total, 40 thermocouples were inserted into each house.

The layer of 25 mm high and a path of 50 mm wide with elliptic shape were used. Printing was conducted with the use of round nozzle with 40-mm diameter. The total printout consisted of 88 layers and the weight of the printed out concrete mixture was equal to 18 tonnes. It gives the output of 670 kg of concrete mixture per hour. The value of expenditure in the case of printouts is a componential of two factors – expense of extruder and shape of the printed path. The expense of the extruder used during printing amounts to maximum 6t/h , the printing however consisted of many short segments (inside the walls) what forced often breaks and slowing down of the printer, what, in turn de-

Fig. 5. Final effects

Fig. 6. Transport of the houses

creased the mean output of the mixture. The concrete mixture was prepared especially for the needs of 3D printing by ATLAS company. The discussed houses had a door opening, the printed reinforced lintel and wall pillar; they did not have a roof. The walls had the thickness of 240 mm and, depending on the site they consisted only of outline or outline with filling in a shape of Z letter. The filling is aimed at the increase of the strength of the printing, and the empty space was filled with the different types of thermal insulation. The walls were reinforced manually with the rods with 6 mm diameter, bent in U letter shape and laid each 5 layers.

After completion of the process, the buildings were wetted with water and then, tightly covered with foil in order to minimize the risk of cracking of the printout. In the case of the mixture intended for 3D printing, the key operation consisted in ensuring the appropriate care of the concrete after completion of the process due to a high inclination of the material to generate the cracks (a high contraction during binding).

The successive stage included transport of the objects to the target site where they would be subjected to fire tests. For loading and unloading, the hangs screwed into the fundamentals were employed.

Conclusions

The printers for the concrete were able to work without a failure during the whole process which lasted finally for 27 h. It is evidence that the technology of print 3DCP is ready for a wide use in construction and prefabrication processes.

During such a long process of printing connected with the constant binding of the concrete in the performance systems, it might be expected to meet the problems connected with the clogging of pumping hoses, mixing elements and material dispensers. Any decline in output of the extruder or pump feeding the material to buffer tank was not observed. There was detected only one problem connected with the removal of the tank of concrete extruder from the mixing device. It was solved by the change of geometry of the buffer mixer.

Fig. 7. Composite reinforcement in the concrete sample

The currently employed material gives the possibility of rising the construction at the rate of 0.3 m/h (experimentally determined). It is a parameter connected with the geometry of the element as well as with the speed of binding of the mixture. The discussed buildings could be ready during 10 h. The shape and structure of the walls were not prepared in this case to 3 DCP technologies, therefore they require optimization. All types of short and complicated paths have a very negative impact on the mean expense of the process; due to this reason, the process becomes prolonged.

Transport of the printed objects goes in the same way as that one of other prefabricated concrete elements. Limitation includes the dimensions and weight of the final product what should be considered in the stage of design of the construction. In the case of necessity, it should be produced in the pieces; another solution may be transport of machine and the building site and performance of the printing "on-site". It has certain advantages such as the possibility of printing of the objects in one process, on the total working area which may be even 15 x 13 x 5 m in the case of REbuild v3. Also, transport of the decomposed machine is simpler (due to utilization of aluminium lattice (grate) the weight of the construction is less than 2.5 t). On the other hand, the drawback includes the dependence on the weather conditions whereas during printing in the manufacturing hall, the mentioned conditions are constant and are, as a rule, favourable for the process of the care of the concrete.

Plans for the further development

The successive step includes production and testing of automatically reinforced constructions, with the utilization of the system for automatic placing of reinforced elements (developed in Rebuild), as being described in the patent application PCT/EP2019/069290) and comparison of the obtained resistance (strength) data and reliability of the process.

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EFFECT OF THE APPLICATION OF OPOKA ADDITIVE IN FEED ON BLOOD MORPHOLOGICAL AND BIOCHEMICAL PARAMETERS AND ANIMAL HUSBANDRY INDICATORS OF BROILER CHICKEN

WPŁYW ZASTOSOWANIA W PASZY DODATKU OPOKI NA PARAMETRY MORFOLOGICZNE I BIOCHEMICZNE KRWI ORAZ PARAMETRY ZOOTECHNICZNE KURCZĄT BROILERÓW

***Summary**: In the paper, the studies on the effect of the application of 1% additive of opoka on morphological and biochemical parameters of blood and animal husbandry indicators (weight increase and dressing percentage) of chicken broilers ROSS 308 were presented. The experiment was conducted in animal facilities of the Department of Animal Nutrition and Biotechnology, Warsaw University of Life Sciences.*

***Keywords**: opoka, silica-calcite sedimentary rock, broilers, blood morphological and biochemical parameters*

***Streszczenie**: W artykule przedstawiono badania wpływu zastosowania w paszy 1% dodatku opoki na parametry morfologiczne i biochemiczne krwi oraz parametry zootechniczne (przyrosty i wydajność rzeźną) kurcząt broilerów ROS 308. Doświadczenie przeprowadzono w zwierzetarni Katedry Żywienia i Biotechnologii Zwierząt SGGW w Warszawie.*

***Słowa kluczowe**: opoka, krzemionkowo-kalcytowa skała osadowa, broilery, parametry morfologiczne i biochemiczne krwi*

Introduction

Opoka is a silica-calcite sedimentary rock – seabed, composed of the residues coming from marine organisms dating back to the Upper Cretaceous period. It occurs in the area of the North Sea, at the territory of Poland, Lithuania, Ukraine and Russia. Its chemical structure and a high porosity cause that it is an excellent absorber [1]. Until now, there have been conducted the studies on the application of opoka mainly as the sorbent in the treatment of municipal sewage [1 – 3]. Its use in agriculture and gardening with the aim of a slow penetration of the elements to the soil is also well documented [1, 3].

Similar materials, mainly diatomaceous earth (DM), were already earlier used as growth stimulators, natural source of silicon in farm animals, the anti-parasite agent, or mycotoxin absorbents [4, 9]. Bennett et al. (2011) showed that 2% additive of diatomaceous earth to feeds for laying hens had the influence on the evident decrease of the number of eggs of *Capillaria* and *Heterakis* parasites. Besides it, the hens from the experimental group had higher body weight and were characterized by higher laying performance. The studies of Łukasiewicz and Wiewióra [9] indicate that DM addition in feed for the broilers resulted in the higher participation of breast muscles and lower fattening of carcasses in the group, receiving 4% additive of diatomaceous earth as compared to the control group, with the simultaneous lack of the effect on chemical composition of the muscles. Moreover, it was found that femurs (thigh bones) of the animals from the group receiving 4% DM additive were characterized by a significantly higher strength as compared to the chicken from the control group [9].

Due to the similarity in chemical and physical structure, it may be expected that opoka will have the similar properties as DM. In the earlier work, Makarski et al.(2020) [5] demonstrated that 1% addition of opoka had a positive influence on the quality of broiler meat via increase of collagen and ash content and lowering of fat level in leg muscles [5]. According to our knowledge, more experiments where opoka was used as food additive for animals have been not carried out.

The aim of the present study was to evaluate the effect of the application of 1% addition of opoka in the diets on morphological

and biochemical parameters of blood and animal husbandry parameters (live weight gains and dressing percentage) of broilers ROSS 308.

Material and methods

The experiment was conducted in animal facilities of the Department of Animal Nutrition and Biotechnology, Warsaw University of Life Sciences. In the henhouse, the controlled conditions were maintained, i.e. temperature from 32°C for the first 12 days – decline by 1°C per day until reaching 21°C; the range of humidity 64–70%; cycle light/darkness 20/4h for the first 10 days, and then, 20/10h until the end of the experiment. The animals had a free access to water and feed.

One day-old ROSS 308 broilers were classified into 2 groups (control and experimental). The number of the birds was: 12 females and 12 males in each group. The diets, starter (from1 to 14 day of life) and grower (from 15 to 42 day of life) were developed according to NRC requirements (1994). The chicken from the control group were *ad libitum* fed the standard diet. The animals from the experimental group received the standard diet, supplemented with 1% opoka addition, i.e. silica-calcite sedimentary rock, supplied by the Manufacturing Plant of

Table 2. Chemical composition of natural Opoka

Component	Natural Opoka*	
SiO_2	52.10	37.20
CaO	19.30	28.20
MgO	0.69	0.58
Al_2O_3	5.75	3.82
Fe_2O_3	1.80	1.79
K_2O	1.05	0.71
Na_2O	0.13	0.12
TiO_2	0.37	0.24
P_2O_5	0.03	0.04
MnO_2	0.01	0.02

** Brogowski, Renman 2004*

Table 1. Components of feeds

Commercial component diet[1]	Control group		Experimental group	
	Starter	Grower	Starter	Grower
	%			
Wheat	10	10	10	10
Maize	48.7	49.7	47.9	48.7
Soy bean meal 46%	32.6	31	32.7	31.4
Soy bean oil	3.5	3.82	3.5	3.85
DL-methionine 98%	0.2	0.1	0.2	0.05
L- Lysine 99%	0.2	0.34	0.2	0.35
Threonine 98.5%	0.1	0.1	0.1	0.1
Limestone	1	1	0.7	0.7
Monocalcium phosphate	2.4	2,6	2.4	2.6
Sodium chloride	0.34	0.34	0.34	0.34
Premix [2]	1	1	1	1
Opoka	0	0	1	1
Metabolizable energy MJ/kg [3]	12.2	12.35	12.1	12.26
Crude protein g/kg [3]	210.0	210.0	200.0	200.0
Calcium *	10.5	10.4	10.6	10.9
Phosphorus *	4.7	5.01	4.7	5.02

[1] *NRC (1994)*
[2] *In 1 kg of premix diets: vitamin A 15 000 IU; vitamin D 3000 IU; vitamin E 20 mg; vitamin K_3 2.7 mg, vitamin B_1 2.5 mg; vitamin B_6 0.4 mg; vitamin B_{12} 0.015 mg, nicotinic acid 25 mg; pantothenic acid 8 mg; folic acid 1.2 mg; Choline chloride 450 mg; DL-methionine 1.0 mg; Mn 74 mg; Fe 30 mg, Zn 45 mg; Cu 4 mg; Co 0.4 mg; I 0.3 mg*
[3] *Calculated*
** Experimental feeds were corrected for Ca content from $CaCO_3$ contained in the rock (169.8 g Ca per 1 kg of rock) or Ca value corrected for opoka $CaCO_3$ content (169.8 g Ca per 1 kg of rock); Brogowski and Renman, (2004)*

Feeds and Concentrates in Kcynia (Poland). The components of feeds have been presented in detail in Table 1. Opoka used in the experiment came from Polish beds and was ground to consistency of flour. Its content has been presented in Table 2.

Mortality, feed intake and individual body weights were currently monitored. Slaughter was carried out in 42th day of life.

During the slaughter, the peripheral blood samples were collected.

Carcasses were chilled by the air method at temperature of 4°C for 24 h. Then, the dissection was performed following the methodology, described by Ziołecki and Doruchowski (1989). **Dressing percentage**, i.e. the content of muscles and the content of giblets, in relation of the body weight before slaughter was calculated. The collected breast and leg muscles were weighed, protected and left for further analyses.

Neubauer's haematological chamber was used for Red blood cell (RBC) and white blood cell (WBC) determination, with Natt and Herrick's solution used as a solvent. The remaining blood parameters were studies in the commercial veterinary analyzers.

The obtained results were statistically processed by two-way ANOVA and Duncan's multiple range tests using the Statgraphic 4.1 Plus software package (StatPoint, Inc., USA). The differences with $P<0.05$ were considered significant.

Results and discussion

The assessment of physiological state of poultry is based, to a great extent, on haematological and biochemical indicators of blood which are the invaluable tools, helping the vets to understand the health state of the birds.

The results of the haematological parameters of blood are given in Table 3. The application of opoka affected significantly the increase of the haemoglobin level in red cells (MCHC), the mentioned values did not however exceed the typical readouts for ROSS broilers in the discussed period of their life [6]. Haemoglobin plays the important role in support of metabolic activity of the chicken. It seems that the increased MCHC coefficient, as a result of supplementation with opoka, may be the answer of the chicken organism to better oxidation of the cells [7].

The results indicate that Opoka may possibly have an immunostimulating effect. Previously studied mineral materials, particularly aluminosilicates, have also been shown to enhance the immunity of chickens [6]. Other hematological parameters remained unchanged following the Opoka introduction to the feed mixture. This suggests that the use of Opoka as a feed additive does not negatively impact the hematological parameters of the blood.

Biochemical parameters of blood are given in Table 4. Any significant changes in the experimental groups as compared to the control one have not been found. The results indicate that the application of opoka as feed additive does not affect the biochemical blood parameters.

The addition of opoka has not also affected significantly the final body weight, feed conversion rate and mortality of the chicken broilers (Table 5).

Table 3. Haematological parameters of blood of broilers fed the standard (control) and experimental (with addition of 1% of opoka) diets

Parameters	Group		SD	p-Value
	control	opoka		
RBCx 10^{12}/l	2.56542	2.64125	0.4570	0.5710
Ht%	23.8333	23.9583	2.4077	0.8595
Hb g/dl	7.48708	7.18167	1.2791	0.4140
MCV um^3	94.2083	93.0167	16.1354	0.8012
MCH pg	29.4292	27.75	5.7554	0.3174
MCHC g/dl	31.6042 b	**35.7292 a**	3.91078	0.0001
WBC x 109/l	19402.1	20240.0	4477.37	0.6296
OB. mm/60min	4.70833	3.47917	2.2730	0.0602
Lymphocytes	55.75	53.125	10.4003	0.3877
Heterophils	37.75	38.5417	10.5608	0.7983
Eosinophils	1.70833 b	**2.95833 a**	2.0035	0.0291
Basophils	3.83333	4.41667	2.2181	0.3679
Monocytes	0.958333	0.958333	1.1101	1.0000
H/L	0.719583	0.865833	0.5717	0.3813

Means within a column with different superscripts are significantly different: a, b at P ≤0.05

Table 4. Biochemical parameters of the chicken fed the standard (control) and experimental (with addition of 1% of opoka) diets

Parameters	Group		SD	p-Value
	control	opoka		
ASPAT (IU/l)	506.73	457.65	126.6690	0.2024
ALAT (IU/l)	14.88	15.40	4.9180	0.7312
Glucose. (mg/dl)	191.19	188.94	22.8632	0.7483
Uric acid (mg/dl)	2.30	2.60	0.9062	0.2700
Urea (mg/dl)	5.10	5.27	1.2051	0.6489
Total protein (g/l)	23.31	23.18	2.7797	0.8730
Alb. (g/l)	15.31	15.27	1.4719	0.9198
Cholesterol (mg/dl)	150.02	139.80	20.4629	0.0980
TG (mg/dl)	32.09	34.85	9.8749	0.3586
VLDL (mg/dl)	6.42	6.97	1.9656	0.3555
HDL (mg/dl)	110.98	105.33	14.9025	0.2124
LDL (mg/dl)	40.11	38.94	8.9918	0.3951
Ca (mg/dl)	6.79	6.81	1.1435	0.9484
P (mg/dl)	6.64	7.01	1.2743	0.3451
Mg (mg/dl)	2.43	2.44	0.2773	0.9064

Table 5. Growth performance of broilers

Parameters	Group		SD	p-Value
	control	opoka		
Body weight (g)	3102.21	3050.17	279.279	0.5244
Feed conversion ratio (kg)	1.46	1.50	0.0186	0.1778
Mortality (%)	0	0	0	0

In relation to the analyzed parameters, significant differences were demonstrated in dressing percentage – its highest value was recorded in the control group, whereas the lowest one was found in the opoka group (Table 6). The application of opoka in the diet for broiler chickens reared until 42nd day of age had not a significant effect on the contribution of breast and leg muscles in carcasses. A higher share of giblets was found in the opoka group, but this difference was not statistically significant. The analyses demonstrated significantly lower abdominal fat content after the diet with 1% of opoka. In their studies, the other authors [9] obtained a similar result in respect of dressing percentage and the decreased percentage participation of muscles of the particular body parts, especially of the leg muscles. The addition of opoka to the feed may affect positively the musculature of the legs as compared to the diatomite earth (DM), employed by other authors. The addition of opoka to the diet has also a positive effect on the quantity of giblets obtained from the chicken in the discussed experiment. Their participation in the carcass weight was considerably higher than in the case of the similar experiment of other authors [9]. A special attention should be paid to the lowered level of depot (abdominal) fat in the birds from the experimental group. It confirms the earlier results where the lower fat content was found in the breast muscle of broilers after the application of opoka additive in the feed [5].

Table 6. The mean results of the slaughter analysis of broiler chicken (%)

Parameters		Group		SD	p-Value
		control	opoka		
Dressing percentage		76.23 a	75.02 b	0.2975	0.0101
Muscles	breast	29.19	28.03	0.6058	0.1907
	legs	20.42	20.41	0.7805	0.9914
Giblets	gizzard	1.38	1.49	0.0650	0.2776
	heart	0.67	0.67	0.9853	0.0378
	liver	2.11	2.26	0.0783	0.1955
Abdominal fat		0.53 a	0.49 b	0.0266	0.0301

Means within a column with different superscripts are significantly different: a, b at P ≤0.05

Summing up

In summing up, we may state that 1% addition of opoka to the standard diet for broilers – did not have a negative effect on biochemical and hematological parameters of broilers. The increase of the level of eosinophils and the earlier studies of the similar materials suggest that opoka may have the immune-modulating properties. Moreover, the application of opoka has decreased the final amount of fat tissue and dressing percentage, without any impact on the quantity of muscles and giblets in the carcasses.

The results of the studies indicate that opoka is a safe material for the chicken. There is a necessity of conducting the further studies with the aim to confirm the immune-modulating properties.

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IDENTIFICATION OF PHASE PERCOLATION IN BAINITIC STRUCTURES

IDENTYFIKACJA PERKOLACJI FAZ W STRUKTURACH BAINITYCZNYCH

Summary: *The aim of this study was to identify and study the phenomenon of phase percolation in bainite structures. SEM microscopic tests were carried out on bainitized iron alloy samples, in the FEM tests austenitic SS316 steel was used as the filled phase. Physical models, which were produced in the form of cubes and tensile samples, were made in FDM technology on the Original Prusa Mini+ printer from ASA filament (modified ABS copolymer). The static tensile test was performed on a LabTest 5.20 SP1 testing machine at a tensile speed of 10mm/min. Complex states of stress in the analyzed systems were identified, which prove the complexity of the phenomenon in multiphase materials. The obtained results were correlated, which allowed to indicate that the phenomenon of percolation indeed affects the mechanical properties of multiphase materials and incremental techniques can be used to analyze the level of this impact.*

Keywords: *phase percolation, bainite structures, mechanical properties of multiphase materials, incremental techniques*

Streszczenie: *Celem pracy było rozpoznanie i zbadanie zjawiska perkolacji fazowej w strukturach bainitu. Badania mikroskopowe SEM przeprowadzono na bainityzowanych próbkach stopu żelaza, w badaniach MES jako fazę wypełnioną zastosowano stal austenityczną SS316. Modele fizyczne, które wykonano w postaci kostek i próbek rozciągliwych, wykonano w technologii FDM na drukarce Original Prusa Mini+ z filamentu ASA (modyfikowany kopolimer ABS). Statyczną próbę rozciągania przeprowadzono na maszynie wytrzymałościowej LabTest 5.20 SP1 przy prędkości rozciągania 10 mm/min. Zidentyfikowano złożone stany naprężeń w analizowanych układach, które świadczą o złożoności zjawiska w materiałach wielofazowych. Uzyskane wyniki skorelowano, co pozwoliło wskazać, że zjawisko perkolacji rzeczywiście wpływa na właściwości mechaniczne materiałów wielofazowych, a techniki przyrostowe mogą być wykorzystane do analizy poziomu tego oddziaływania..*

Słowa kluczowe: *perkolacja fazowa, struktury bainitu, właściwości mechaniczne materiałów wielofazowych, techniki przyrostowe*

Introduction

Percolation in materials is most often described as a process in which a liquid or gas diffuses through a network of interconnections in a porous material. This is an important phenomenon in fields such as materials science, chemistry, chemical engineering and environmental science. There are several methods of recognizing percolation in materials, depending on its type and expected results. Among commonly used methods distinguished are:

- Porosity analysis: The use of microscopic techniques such as optical or electron microscopy allows examine the structure of the material and identify porosity. Image analysis can provide information on pore size, shape and distribution, which can help identify potential percolation paths.
- Electrical conductivity measurement: This technique is particularly useful for conductive materials such as metal or conductive polymers. Electrical conductivity measuring devices such as multimeters or impedance analyzers can be used to monitor changes in conductivity as liquid or gas penetrates.
- Permeability tests: To assess percolation in porous materials such as rocks, soils or filter membranes, permeability tests can be performed. For example, a permeametric test can measure the flow of liquid through a sample of the material and provide information about percolation.
- Computer simulations: recognizing percolations in multiphase materials can be difficult with traditional methods, so computer simulations are used in many cases. Numerical models and simulations can help analyze and visualize the percolation process in the material.

It should be noted that the appropriate percolation detection method depends on the specific material and the purpose of the test.

Percolation is characteristic of porous or non-metallic materials with networks of connections between the pores. In metal structures, such as monolithic metal blocks or sheet metals, there are typically no pore networks through which liquid or gas can penetrate. If there are porous structures in the metal structure, e.g. in metal composites or metal coatings on porous substrates, there is a possibility of percolation through these porous structures. In such cases, percolation may refer to the

penetration of a liquid or gas through the pore network connections of those porous materials that are present within the metal structure.

In the literature, however, the term "phase percolation" can be found, which refers to the phenomenon of percolation occurring between different phases or components in a composite material. In composite materials, two or more distinct phases are combined to form a material with desired properties. These phases can be different materials, such as polymers and fillers, or different states of matter, such as solid and liquid.

Phase percolation occurs when a continuous path or network forms between the phases, allowing physical or chemical properties to be transferred throughout the composite material. This percolation network can allow different quantities to be transported, such as electrical conductivity, thermal conductivity or fluid flow, depending on the specific properties of the phases involved.

The percolation threshold is an important concept in phase percolation. It represents the critical volume or concentration at which a single-phase interconnected lattice begins to form in a composite material. Below the percolation threshold, the phases remain isolated and do not significantly affect the overall material properties. Once the percolation threshold is reached, there is an abrupt change in the behavior of the material as the interconnected network of the percolating phase begins to dominate the properties of the composite. By controlling the percolation behavior, composite properties can be optimized and advanced materials with properties tailored to specific applications can be developed [1].

Influence of percolation on mechanical properties

Percolation can have a significant effect on the mechanical properties of multiphase materials. When a composite material percolates, the formation of an interconnected network or path between the different phases can affect its overall mechanical behavior in several ways:

- Strength and stiffness: The presence of percolation paths can increase the overall strength and stiffness of the composite material. The material's load capacity increases as stresses are transferred more efficiently between phases through the percolation network. This can result in improved mechanical properties such as increased tensile strength, compressive strength and Young's modulus.
- Strength and Fracture Resistance: Percolation can also improve the strength and fracture toughness of composite materials. The interconnected network provides stress redistribution and energy dissipation paths, preventing crack propagation and increasing the material's ability to absorb and withstand applied loads without catastrophic failure.
- Elastic behavior: The presence of percolation paths can affect the elastic behavior of the composite material. Percolation phases can contribute to the overall elastic response by affecting parameters such as elastic modulus and Poisson's ratio. The stiffness and deformation characteristics of the composite may be influenced by changes in the material microstructure caused by percolation.
- Anisotropy: Percolation can introduce anisotropic behavior in composite materials, meaning that their mechanical properties can change depending on the direction. The orientation and placement of the percolation paths can affect the material's response to different types of loads, resulting in different mechanical properties along different axes or directions.

It should be noted that the extent and nature of the percolation, including the percolation threshold, the morphology of the percolation network, and the properties of the phases involved, can play a role in determining the specific effect on mechanical properties. Therefore, optimizing the percolation behavior is a key factor in designing composite materials with desirable mechanical properties for various applications. Therefore, scientific work is undertaken aimed at building physical models testing various types of phase percolation in search of the best individual properties of the material. This paper focuses on austenite percolation in bainitic structures.

Austenite percolation in polycrystalline structures

In the context of solid structures, especially in the presence of multiple phases, the term "percolation" can be used to describe the spatial connectivity and propagation of a particular phase in a microstructure (Fig. 1).

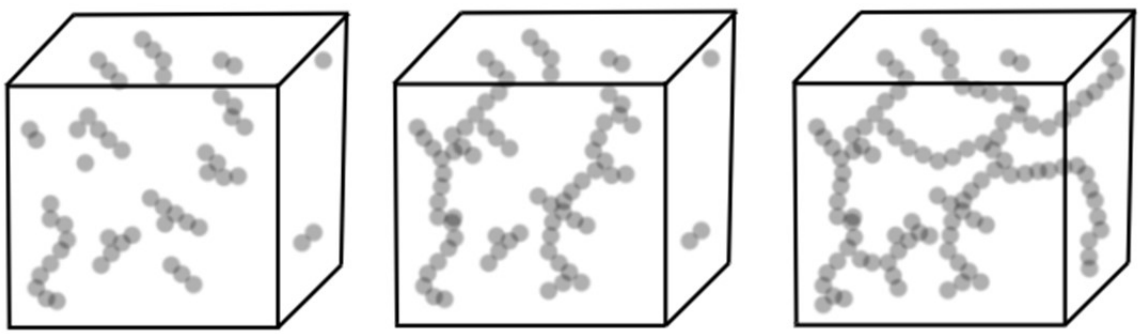


Fig. 1 Schematic illustration of critical volume fraction in the percolative network of spherical inclusions in the random distribution: a) without percolation; b) critical volume fraction percolative network; c) percolative network cluster

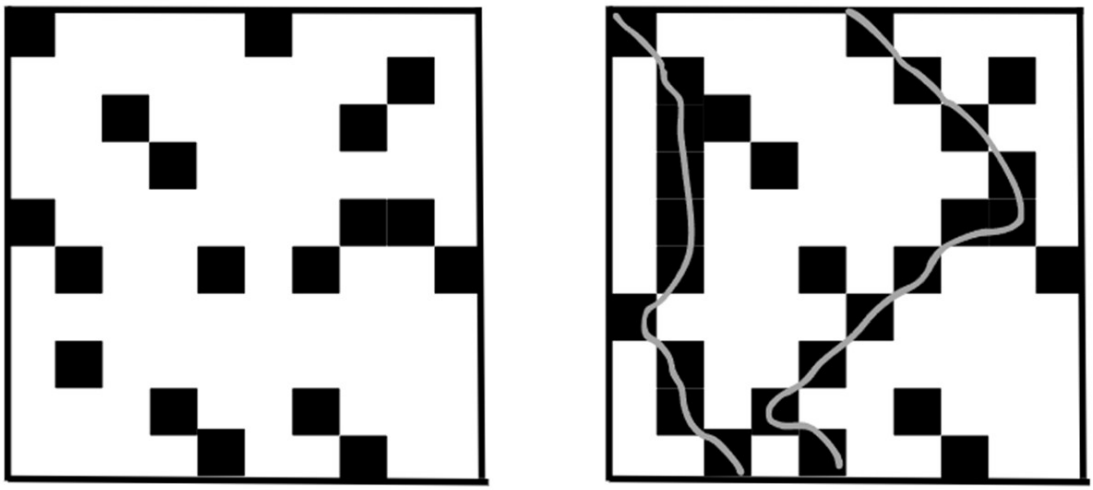


Fig. 2. Percolation illustration: a) black phase is below this threshold; b) black phase contributes above the percolation threshold

In the case of austenite, percolation may occur in solid structures containing a mixture of austenite and other phases, such as ferrite or cementite. Percolation refers to the phenomenon in which the austenite phase forms a continuous path throughout the material, connecting multiple regions or grains [2]. This interconnected path allows specific material properties to be affected, e.g. hydrogen diffusion in bainitic steel [2] or yield strength in duplex steel [3].

The percolation of austenite in solid structures depends on various factors, including temperature, time, composition, and the presence of nucleation sites or defects. The kinetics and extent of percolation can be affected by atomic diffusion, growth of new phase regions, and movement of phase boundaries. However, a method of determining it must be found.

Experimental techniques such as microscopy, diffraction and thermal analysis can be used to observe and analyze austenite percolation in solid structures. These techniques provide insight into the evolution of the microstructure and connectivity of the austenite phase. Physical modeling techniques can also be used for this analysis, but this requires a high level of understanding of the mechanisms that create the percolating structure.

Percolation of austenite in bainite

The transformation of austenite into bainite occurs through the nucleation and growth of a new phase (ferrite) that occurs within the existing austenite grains (Fig. 3). In the case of modern nanobainitic steels, the transformation results in a microstructure with a unique morphology of fine, lamellar ferrite in an austenite matrix with little or no carbide precipitates. The extent and kinetics of nanobainite formation depend on such factors as temperature, alloy composition and time [4]. Recently, the best property indicators have been documented when only ferrite and austenite (Fig. 3b) are present in the microstructure - such a structure model was adopted for the analysis [4].

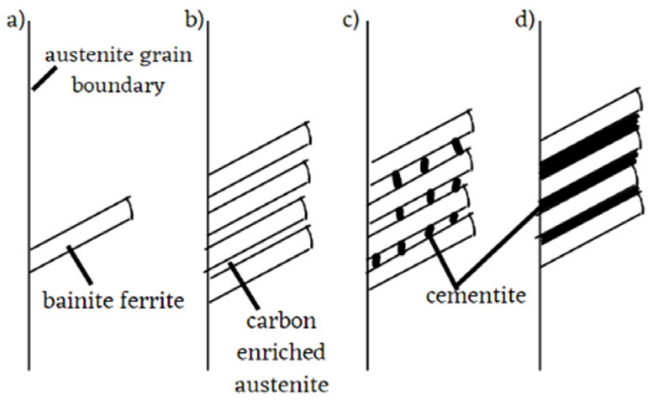


Fig. 3. Scheme of the formation of upper bainite a); b); c); d) successive stages of transformation

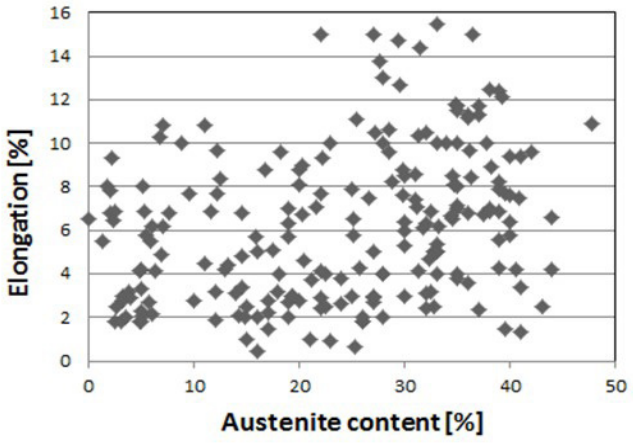


Fig. 4. Dependence of elongation on the share of austenite in the structure of austempered ductile iron

In the case of heat-treated iron alloys, e.g. bainitic steel or austempered ductile iron, it is known that the increasing volume fraction of austenite changes the mechanical properties, but this change is difficult to justify with simple dependencies

[5]. Austenite is a plastic phase, so it would be natural for the material to become more plastic as the volume fraction of this phase increases. However, the dependence of the elongation determined in the static tensile test as a function of the austenite share shows that additional indicators are needed to describe the spatial structure of the material (Fig. 4). In addition, it was proven that below 10% of austenite, brittle cracking of the material occurs due to the breaking of austenite percolation chains [5,8].

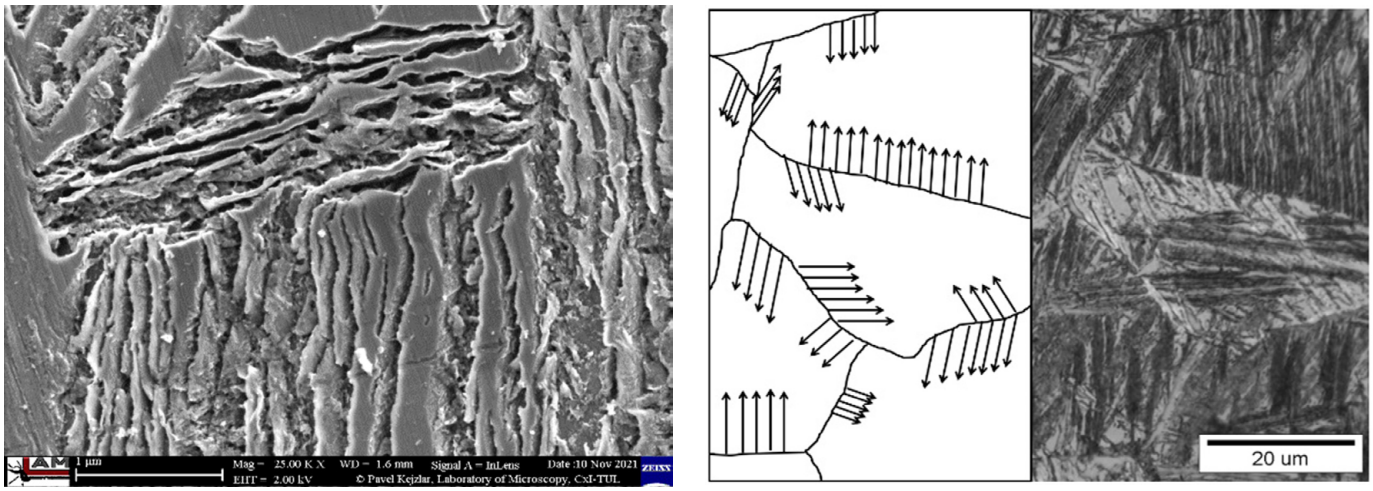
This observation can be understood if one assumes that failure occurs when the austenite, which is the hardest of all phases present, becomes geometrically isolated, i.e. loses its percolation, leading to crack formation [6]. Garboczi et al. developed a numerical model for the percolation threshold when freely overlapping objects (ellipsoids) are in the matrix [7]. Since austenite is roughly divided by lamellar ferrite, it can be represented by flattened ellipsoids with an aspect ratio r of about 1/10 to 1/100. It was then found that the percolation threshold is $p_c \sim 1.27r$, i.e. $0.127 \geq p_c \geq 0.0127$. This is consistent with the observation that tensile failure occurs when $V_\gamma \sim 0.1$. It was therefore found that the austenite percolation must occur in order to obtain specific mechanical properties of the structure of the austenitic-ferritic mixture. It was indicated that austenite content of at least 10% results in the continuity of the austenite path. However, the question remains how to visualize it and extract it from the system in order to study the best geometric features of the system.

Creating a model of austenitic-ferritic structure in carbide-free bainite

In order to simplify the task, the creation of a virtual model of a single elementary cell of the austenitic-ferritic structure was started with the assumption that one time and temperature state of the material is considered, in which the heat treatment process of a specific type of iron alloy ends. Growing ferrite plates nucleate and then fill individual grains of austenite. It was therefore assumed that this austenite grain with a specific number and morphology of ferrite plates would represent a single cell of the modeled structure.

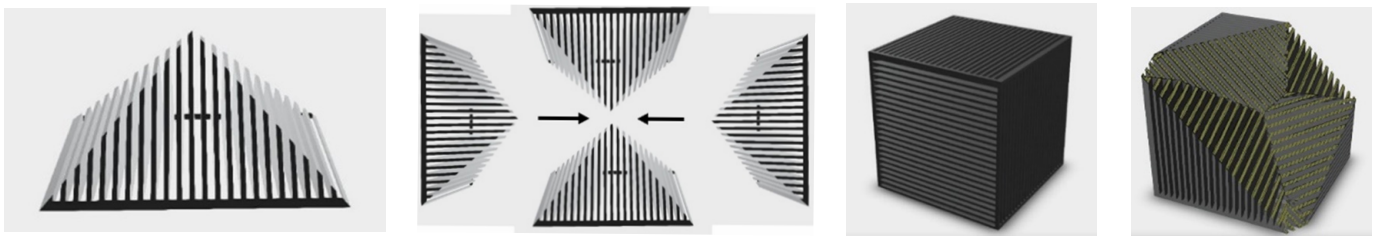
The assessment and analysis of the microstructure of the described mixture of phases shows that ferrite plates nucleate at the boundaries of austenite grains (Fig. 5) and that they have the form of plates visible not only by reconstruction, but also after deep etching and observation in an electron microscope (Fig. 5). For smaller microscopic magnifications, the privileged directions of growth of this structure are also visible (Fig. 5).

Taking into consideration the above assumptions, a simplified model of the structure of a single grain in the structure of carbide-free bainite, i.e. a mixture of lamellar ferrite and austenite, was developed in the SolidWorks program (Fig. 6) This model was called the basic cell. A cross-section through such a cell in non-obvious planes indicates a complex spatial system of two different materials interpenetrating each other.



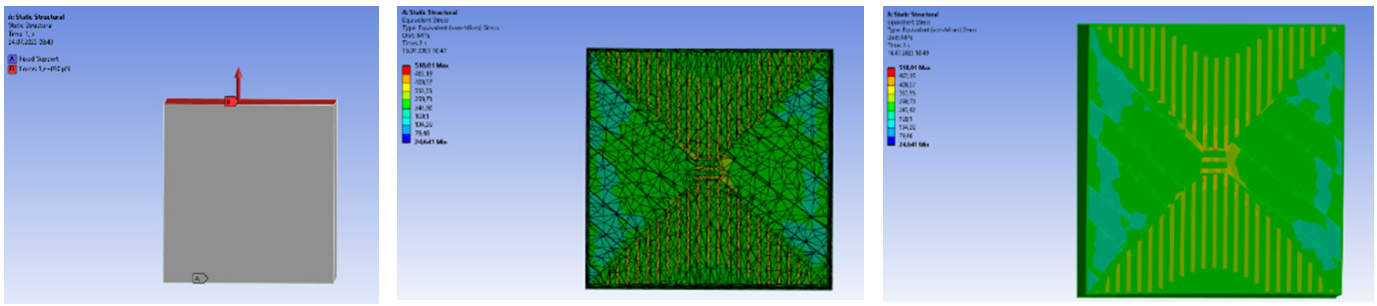
a) b)

Fig. 5. Growth of ferrite plates on austenite grain boundaries; a) SEM visualization of the deeply etched microstructure of the mixture of ferrite plates and lamellar austenite visible in the foreground; b) growth directions of ferrite plates in primary austenite grains in a bainitized iron alloy



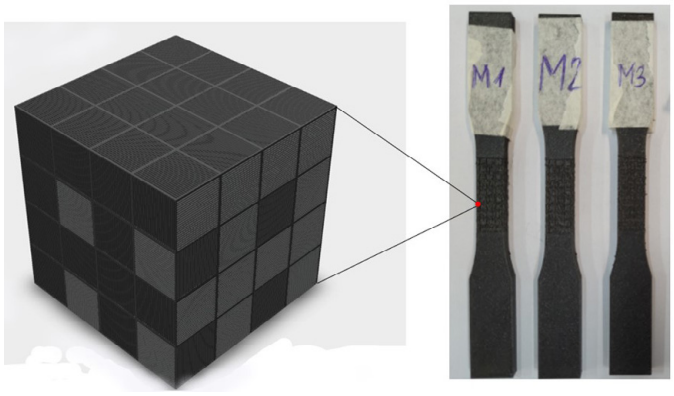
a) b) c) d)

Fig. 6. Construction of the basic cell - model of a mixture of lamellar ferrite and percolating austenite: a) basic element; b) assembly of the basic cell; c) basic cell; d) cross-section through the basic cell



a) b) c)

Fig. 7. FEM analysis carried out on the base cell during static stretching: a) direction of the tensile force; b) FEM mesh within the deformed base cell; c) stress distribution on the cross section of the base cell



a) b)

Fig. 8. A spatial model of the percolating austenite structure (empty spaces reflect the shape of the ferrite plates): a) polycrystal model; b) 3D printed tensile test specimen with a polycrystal model in the measuring part

The model assumed a specific morphology of the austenite and ferrite phases, i.e. the shape of the ferrite plates, but also their thickness, or rather the ratio of the thickness of the ferrite plates and austenite layers separating them at the level of 3:2.

The FEM analysis of the created models allows for the conclusion that, compared to a uniform structure, the basic cell system is characterized by a complex state of stress, which is divided into areas that are more and less susceptible to tensile stress. Material used in the test was SS316. The model was tensile tested by applying a force of 10,000N to the top face/plane of the cube. Fixed support was defined on the bottom face/plane of the cube. Figure 7 shows the von-Mises stress distribution, where the minimum stress value is 24.6 MPa (marked in blue) and the highest is 518 MPa (marked in red).

On the basis of the basic cell, a spatial model imitating the polycrystalline structure was built (Fig. 8a), which was then converted into the form of a strength sample by 3D printing in a polymer material (Fig. 8b). 3D printing was made on the Prusa Mini+ device using ASA filament (modified ABS, UV resistant). The static tensile test was performed on the LabTest 5.20 SP1 device at a tensile speed of 10mm/min. The results of strength tests are presented graphically in Figure 9.

Based on the conducted tests, it can be concluded that the determination of the tensile strength of a full printed structure and one that imitates the structure of a multi-phase material is possible and shows the differences in properties.

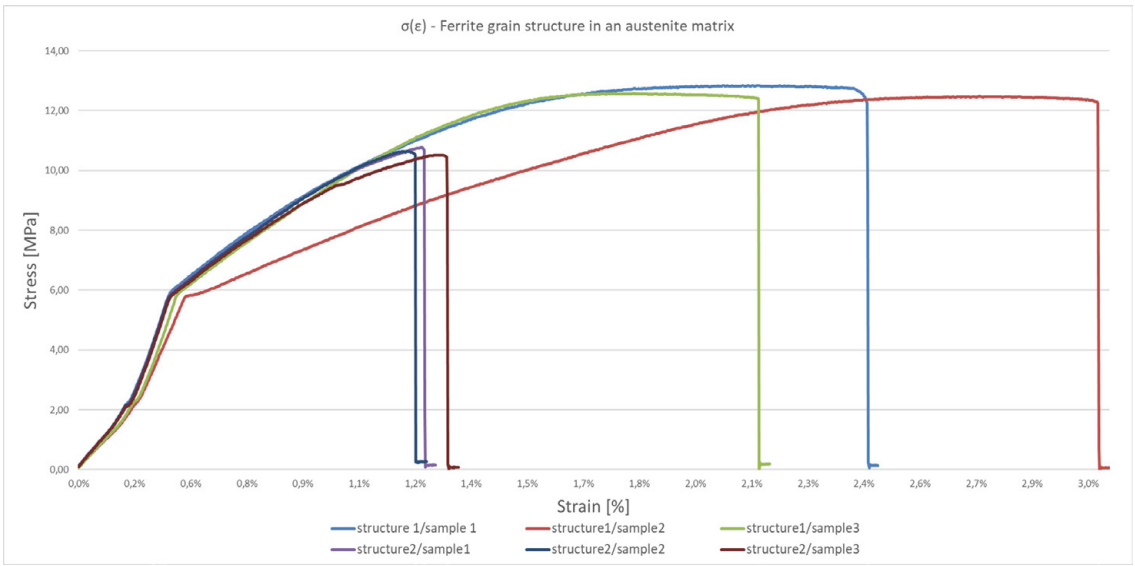


Fig. 9. Strain-stress plot of printed structure 1 and structure 2: Structure 1 is a continuous sample model; Structure 2 is a model of a sample containing a polycrystal based on a basic cell, taking into account only the mapping of the austenite phase (empty spaces reflect the shape of the ferrite plates)

Looking closely at the tensile results of the test specimens, the strength of the percolation structure is naturally lower than that of a full 3D printed cross-section. However, it shows a clearly smaller dispersion of results than in the case of a full cross-section. This may be due to the heterogeneity of the printed structure.

Conclusions

Based on the conducted analyzes and tests, it was found that it is possible to assess the impact of percolation on the mechanical properties of multiphase materials whose structure can be determined by physical modeling. It was found that:

- In some multiphase materials, phase percolation can be identified resulting in a change in specific physicochemical properties of the material,
- Percolation can be determined by various methods appropriate for the tested material, and one of such methods can be physical modeling using modern production methods, e.g. 3D printing,
- Physical models of the microstructure of a multiphase material require a thorough understanding of the phenomena shaping its structural features, but also the geometry of the smallest elements of such

a system,

- Austenite percolates in the bainite structure and can be modeled using computer-aided techniques;
- Incremental techniques can be used to analyze the impact of the percolation phenomenon on the mechanical properties of the structure when analyzing its various variants, with the appropriate selection of print parameters and using appropriate post-print processing techniques

Determining the actual possibilities of modifying the structure using 3D printing requires an in-depth analysis and understanding of the phenomena occurring during the manufacturing process itself.

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HENRYK GÓRECKI – THE MAN WHO MADE AGH, A UNIVERSITY ORIGINALLY KNOWN AS THE ACADEMY OF COAL AND STEEL, FAMOUS IN AUTOMATION, ELECTRONICS, IT, TELECOMMUNICATIONS AND BIOMEDICAL ENGINEERING

HENRYK GÓRECKI – CZŁOWIEK, KTÓRY AGH, UCZELNIĘ PIERWOTNIE ZNANĄ JAKO AKADEMIA WĘGLA I STALI, UCZYNIŁ SŁAWNĄ W AUTOMATYCE, ELEKTRONICE, INFORMATYCE, TELEKOMUNIKACJI I INŻYNIERII BIOMEDYCZNEJ

Professor Henryk Górecki, about whose achievements I would like to tell in this paper, was the prominent scientist and engineer, graduate and worker of AGH University of Kraków for all His life. AGH is one of the greatest Polish technological universities. Prof. Górecki performed great transformations in the history of the international science, made the extreme contribution to development of Polish engineering, conducted the radical changes in his *alma mater* and, also, created my own career and life. Therefore, when on December, 20, 2022, I had the occasion to speak at his open grave, I commenced from the following words:

– It is the end of certain epoch.....

It is true that together with the passing away of Prof. Górecki, a certain epoch has been ended in the history of AHG and in the domain of automation.

We used to speak about one of the Polish Kings that he "found Poland in wood and left it in brick". We may say about Professor Górecki that he found the Electric Department of AGH as being highly mining-metallurgy-oriented unit and left it as a department famous of its achievements in respect of automation, electronics, computer science, telecommunication and biomedical engineering.

He performed it owing to extreme wisdom, patient work and persistence in his deeds.

When he graduated in 1950, he commenced to work at the Chair of Mining Electrification. He defended his doctoral thesis in 1956 and obtained the post of associate professor and began to implement his great ideas. In 1957, he founded the **Department of Automatics Backgrounds**. At the beginning, the mentioned unit had only three employees but had the enormous intellectual potential which made that as early as in 1960 it became developed and transformed into the **Chair of Automatics and Industrial Electronics**.

Fig. 1. Prof. Henryk Górecki with prof. Ryszard Tadeusiewicz, 2017
Source: author's archive

For Professor Górecki, the word "impossible" did not exist. When he encountered the obstacles, he tried the unusual but ef-

fective solutions. To organize the practical work of the students in contact with the advanced automation and electronics systems, Professor Górecki obtained the bomber from the army. The mentioned scrapped airplane was full of modern (as for those times...) electronic devices and automatic systems. The co-workers of Professor Górecki disassembled patiently the mentioned elements and constructed the successive laboratory posts in which the students acquired practical competences, developing the theoretical knowledge which was supplied by Professor Gorecki during his lectures. We should mention that the level of the mathematical advancement of the discussed lectures was very high.

To organize the student and scientific laboratories on the basis of the mentioned above bomber (*inter alia*, of course), there were necessary the appropriate rooms. There was always a lack of such place at the quickly developing department of AGH. To solve the problem, Professor Górecki obtained the corridor in the connector, joining the pavilions B1 and B2. Today, the mentioned area has been completely rebuilt and there is a lot of place there; it comprises the greatest lecturing hall of the faculty (H24). But during the start of automation and electronics, there was really only **the corridor** in a narrow passage where the laboratory tables were arranged against the walls. The research work and student practice were carried out just there.

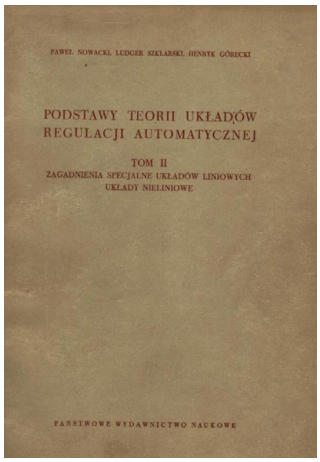
When the army saw such good utilization of the bomber, they offered a scrapped tank to Professor Górecki. The mentioned proposal was not utilized as the advanced systems of automation and electronics in tanks were to appear in the tanks in decades later so it could not give any profit during the discussed period.

Moreover, at the end of the sixties of 20th century, the students had also another device at their disposal. It was imported by Professor Górecki from DDR (German Democratic Republic) and was called Regelkreis. We named it "water brain". It was a system in which it was possible to program a dynamics of different object of steering (control) and models of different regulator; the dynamic processes, occurring in the whole system, could be observed in a form of flows of stained liquids in transparent pipes. It gave the similar possibilities as computer stimulation gives nowadays. The classes were so interesting that we did not paid attention to the persons who passed constantly from B1 to B2 in both directions (because the function of corridor was all the time maintained).

I constructed my electronic dog just at the discussed place; it was equipped with the elements of AI, what was the subject of my MSc thesis.

When I already allowed myself to insert here the personal elements I would like to add that when I passed (1965) the entrance examination to AGH, I was writing it at the lecture room at the 3rd floor of pavilion B. At the vicinity, there were the doors to paradise which I wanted so much to enter. Good luck made that my dream became true!

The Chair of Professor Górecki was developing and had more and more scientific successes (it will be discussed later on) and in 1969, it became transformed into Institute of Automation



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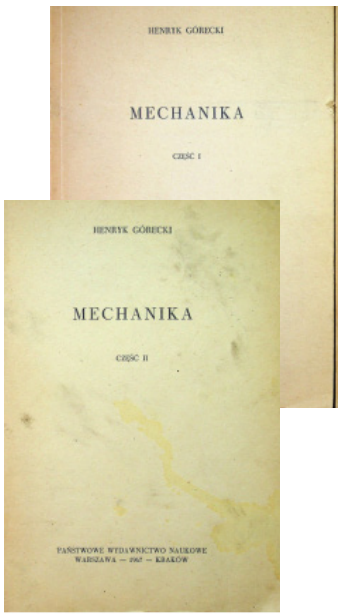

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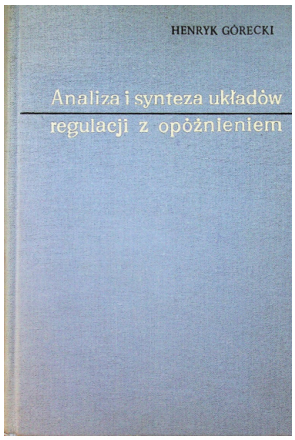

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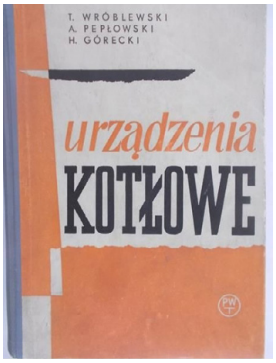

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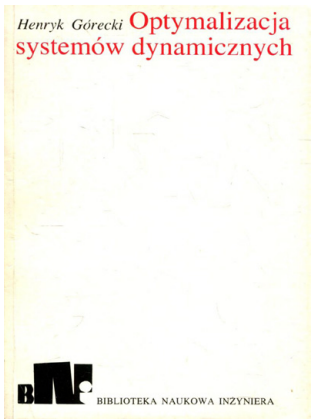

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Fig. 2. Book publications by Prof. Henryk Górecki

and Industrial Electronics (IAEP). In the same year, I managed to enter the experimental student group where we acquired the knowledge in the field of automation and tele-mechanical engineering. I was happy as I could listen to the lectures of Professor Górecki. At his request I recorded his lectures in a written form and consulted the context with Professor as it was to be a new handbook of automation. Professor wanted to publish it as a successive part of monograph: "The basis of the theory of automatic regulation systems" (the authors of the first two parts of the monograph were: Paweł Nowacki, Ludger Szklarski and Henryk Górecki).

The consultations of the recorded lectures were somewhat difficult as when Professor was present in his cabinet, the entrance to his room was guarded by his secretary, Mrs Isabel (Zula) Zawadzka.

– Professor is resting! – She used to say.

It was a barrier impossible to be passed.

I was not so bold as to bother Professor at his house and the short exchange of opinions at the corridors was not sufficient to form finally the whole range of the topics of Professor lectures, being based upon the theory of control, optimization and automatic regulation. In effect, the mentioned book based on my records from the lectures by professor Górecki was not created but the records were often used by the numerous students who prepared themselves to the examinations. They appreciated the mentioned elaboration and used them for several years.

Allow me also to refer once again to my own experiences as they are – in my opinion – a very meaningful evidence of the professor's silhouette: what man he was and how he acted.

Similarly as the majority of my colleagues from the mentioned above group, specializing in automation and tele-mechanics, I wanted very much to work in the Institute, guided by Professor Górecki. I evaluated my chances as being very small because my "competitors" derived from the eminent Cracow professor families whereas I was a son of accountant form Myślenice...

So, I was much surprised when after the defence of my MSc, during which I presented the mentioned above electronic dog, Professor Górecki came up to me and said:

– "Richard, I have already sent information that you applied"
– "Professor, where I could apply?" –
– "Well, for work at my Institute".

It was the happiest moment in my life!

Indeed, I checked it later in HR department; there was the official letter signed by Professor Górecki that Engineer R.T. M.Sc., applied for work on 1.04. 1971. But the diploma for MSc. is dating back to 2.04. 1971.....

The further successive run of achievements and successes of Professor Górecki may be described by me as first-hand information as assistant, adjunct, associate professor and professor at the Institute guided by professor, Deputy Director of the Institute and, later on his successor to a certain degree (after retirement of Professor Górecki, I became the Head of his Chair).

I would like to stress the fact that the whole work of Professor Górecki was characterized by a high level of mathematic advancement. His scientific papers were especially highly advanced and refined in respect of mathematics but the lectures for the students were also found at the high level what made what he (technician!) became the member of Polish Mathematical Society and American Mathematical Society. He had a person who helped him in solving difficult mathematical problems. It was the friar, Benedictine from Tyniec, priest professor Andrzej Turowicz whom Professor Górecki dared to invite for the lectures for his students and later on, made him the regular lecturer at the Doctorate Student Centre, created by the Professor. (1969). In the sixties and seventies of the XXth century, it require a great courage as the Communist party, being very strong in those years at AGH, became furious when perceiving the lecturer in habit; Professor Górecki resisted, however, the pressure and owing to it, his students and doctoral candidates had the best mathematical preparation in Poland!

The innovative conceptions and organizational successes of Professor Górecki made that the Institute was quickly developing and constantly extended the range of the research and didactic topics. In 1972, the University Centre of Computer Science of AGH was included into his Institute. It was founded earlier (1966) but it did not function well as a separate unit. Professor Górecki restored it and brought to the state of splendour, lasting until now.

In 1973 a series of transformations was commenced and it brought about generation of the whole series of scientific units within the Institute of Professor Górecki. After obtaining the appropriate degree of "maturity' (under the guidance of Professor Górecki), they were separated and created the independent chairs and institutes, giving a meaningful contribution to the Faculty and the total University. The first step towards this direction was made by independence (1973) of the group of the employees of IAEP who created the self-governing **Institute of Electronics**. At the same year, Professor Górecki organized the **Independent Unit of Biocybernetics** and entrusted me with the function of the head of it. At present, the Faculty includes the Chair which strongly develops biomedical engineering.

After departure of the electronic engineers, the Institute of Professor Górecki adopted the name of **Institute of Computer Science and Automatics** (until 1980). In 1980, the computer science-related part of the staff of the Institute was separated and created the Chair and later on, **Institute of Computer Science**. Due to the fact that the majority of my publication concerned information science problem, there was a general expectation that I would go to the Chair of Computer Science but I remained faithful to Professor Górecki. Our group (being still most numerous at the university) adopted the name of **Institute of Automatics, System Engineering and Telecommunication**. In 1980 I was nominated to the post of Deputy Director of the Institute so I had the direct and indirect impact on its fates. Professor Górecki anticipated the effects of telecommunication development as early as in 1976; therefore, since the mentioned year, one grade of the doctoral students received the education oriented to telecommunication. The mentioned grade yielded, *inter alia*, the long-time manager of Institute of telecommunication and former Vice-Rector of AGH, Prof. Andrzej Pach, and, also, the known business-

man, creator and President of Comarch company, Prof. Janusz Filipiak.

In 1986, according to the expectations, the Chair of Telecommunication was separated from our Institute. Prof. Górecki decided that our group would be called since that moment shortly: Institute of Automatics, as not to make any further divisions.

The change of the name from "Institute" into the "Chair", as being introduced on the administrative way in 1992 did not change anything. At the moment of the mentioned change, the Chair had 12 titular professors, 8 university professors and 4 doctors with habilitation (PhD) and 49 assistant professors (adjuncts in Polish) (not mentioning other employees, 116 persons in total). It was a resource from which it was possible to create at least few chair units. But the ties between the people, generated owing to the personal authority of Professor Górecki caused that the Chair maintained its integrity for many years although it was the greatest chair at AGH and different external pressures were aimed at its division.

I took over such integrated Chair from the hands of Professor Górecki in 1997. Later on, I separated – with awareness and purposefully – the **Chair of Applied Computer Science** and then, I helped to create the **Chair of Biocybernetics and Engineering in Biomedicine** and to transform the remaining part into the **Chair of Automation and Robotics**. I am not going to comment the mentioned undertaken measures as it is not connected with the activity of Professor Górecki (although it was the consequence of his far-reaching decisions).

After this brief review of certain organizational achievements of Professor Górecki, I would like to focus on the Scientific Authority of my Teacher and Master. It cannot be expressed by the bare fact, figures or dates.

All those who followed the development of Polish automation, and, partially also computer science during the recent 50 years know that there are not many persons whose contribution to the development of the mentioned domains would be so commonly recognized and appreciated as the achievements of Professor Górecki.

I could quote here a long list of the problems which were solved by Prof. Górecki, the statements which were proven by him, the problems which were discovered and the automation systems which were constructed by Professor. Such listing would be readable and understandable only for some specialists who remember still the elements of automatics based on the analogue systems as the most of the achievements of Professor Górecki occurred in the second part of the 20th century when the digital technology was not so much developed and popular as now. Therefore, in spite of the fact that the essence of the discussed achievements still remains actual and they are located in highly abstractive regions of the controlling theory and remain true, irrespectively of the progress which has been made in their practical application, due to the evident reasons, the discussed theories are weakly referred to the most advanced problems of automation dating back to the end of the second decade of the 21st century. Due to the mentioned above reasons, they are not always understandable for the current specialists. Hence, at the beginning of my funeral speech, I said about the **end of a certain epoch**. The approach of Professor Górecki, based upon the profound mathematic studies, the final result of which is transferred not earlier than to the implemented automation systems, is not longer used today in practice. At present, we employ the methods of computer simulation, digital support of decision making, the methods of machine learning (especially of the so-called profound, deep learning) and the total developed CAD methodology (CAD = Computer Aided Design). Meanwhile, Professor Górecki developed automatics based not on artificial intelligence (AI) but on the brain effort of appropriately educated engineers.

It is not the proper place to come into details and refer to the specific results of the scientific researches of Professor Górecki but a short outline of the most important achievements would allow placing his activities in the light of the achievements of other researchers.

All know how difficult and important problem is the **phenomenon of instability** in automatic control in the closed systems. It is manifested most frequently in the situation when in the controlled system, the burdensome self-induced vibrations or non-controlled aperiodic processes occur; they lead to "escape' of the object of control and often to a final catastrophe. The mentioned phenomena are extremely dangerous and therefore, the problems of instability and the methods of its control are studied all over the world, constituting one of the most important challenges of the contemporary automation. It is nice to state here that professor Górecki made a meaningful creative contribution to this difficult and interesting "front" domain of automation. He solved some fundamental problems, with the utilization of very advanced mathematic methods.

It is worth noting that Professor Górecki performed his deeds as early as in the sixties that is, really pioneering period for automatics and therefore, he is cited everywhere and indicated as one of the creators of the background on which the whole domain of the contemporary automation and robotics is based. The achievements of Professor Górecki were the basis for the whole generations of automatic engineers and His pupils and students gained the advantage at the beginning of their scientific career as compared to other scientists due to the position of the Master. It resulted in establishing and wonderful development of the unique scientific school at AGH in Kraków.

I will dedicate some attention to the mentioned above school, being the true *opus vitae* of professor Górecki in the later part of this paper. At this moment, I would like to indicate the further scientific results which are the most known scientific achievement of Professor in the international scale.

All automatics engineers know that the most difficult and complex problems of automatic control (steering) appear in a special class of automation systems and namely, in the systems of regulation covering the objects with **delay**. The objects of such type are especially "thankless" in all attempts of automation, as the delay causes that the consequences of regulation are not visible at once and the control system must – to a certain degree – steer the supervised object "in blank", anticipating its future behaviour. It rises enormous practical difficulties which are en-

larged by additional big mathematic problems in the attempts to analyze and synthesize such systems as for their description it is necessary to employ special classes of differential equations with the deviated argument. It is also necessary to define differently the initial and edge conditions, and moreover, overcome the difficulties consisting, *inter alia*, in the fact that the attempts to apply classical engineering calculation methods in the mentioned systems cause in certain cases the absolute impossibility to solve the obtained equations and in other cases, there was the appearance of infinitely many solutions.

The mentioned above problems caused that the researchers and scientists dealing with the analysis and synthesis of steering systems tried to avoid, for many years, the problems connected with systems with delay. It resulted in many practical problems in the field of application of automation during the attempts to automate certain processes e.g. in papermaking factories or in metallurgical plants. The mentioned problems appeared often in practice. Therefore, the obstacles which made other researchers discouraged were the challenge for Professor Górecki. He was the first in Poland and one of the first scientists in the world who undertook the intensive theoretical work, connected with the development – in fact, as a single person – of scientific methods for construction of automatic regulation systems, including just the most inconvenient objects. Professor Górecki as the first recognized the difficulties occurring in the discussed area and as the first suggested the solutions which have been until now employed and are permanently connected with his name. Professor Górecki published his achievements in the field of analysis and synthesis of automatic systems for the objects with delay in the most known scientific periodicals, submitted them during the greatest scientific conferences (he was often invited as the lecturer). Moreover, he collected and published his work in a form of few book monographs which were distinguished by the highest awards and were also translated in other countries. No wonder that the papers of Professor Górecki in the field of theory and technology of steering of the objects with delay are known today and cited all over the world. Professor is known and highly respected Person in the total described domain of knowledge which meanwhile – just owing to his work – has been developed and hardly established from the scientific viewpoint.

The achievements of Professor Górecki in respect of optimization were also extremely meaningful for the development of automation. In the 60ties the mentioned elaborations indicated the completely new possibilities of constructing the regulation systems which ensured optimum and adaptive steering; in the 80ties and 90ties, they undertook the extremely important and (again!) difficult problem of multi-criteria optimization.

As it is known, typical problems of optimization for which Professor Górecki elaborated numerous mathematic methods in the 60ties, consist in automatic selection of the best steering, with the simultaneous preservation of all limitations. The example of the task of such type may be the task of transferring of any massive object from one place into another at minimum time, with the preservation of all limitations, resulting from the maximum

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Special Issue
on "Dynamic Systems, Stability, Controllability, and Automatic Control"

Dedicated to Professor Henryk Gorecki

This special issue of the Bulletin of the Polish Academy of Sciences – Technical Sciences has a unique intention. It is a collection of papers dedicated to Professor Henryk Gorecki (see photo), the famous scientist and the founder of the Automatic Control Institute in the AGH University of Science and Technology (former name Academy of Mining and Metallurgy). For Professor's Gorecki 80th anniversary, a group of his students and friends wrote and put together this set of papers both as a tribute to the Professor and as a symbol of our gratitude.

As an alumnus and the successor of professor Gorecki – someone who has led his Institute for the last ten years – it is my great honour and pleasure to present the content of this volume. I would like recommend to you all the papers included in this issue while providing here few comments. The papers were selected to show their connection with the scientific and didactic ideas introduced and studied by Professor Gorecki. These ideas have now been researched by the authors – former students, co-workers, and certainly good friends of Professor Gorecki.

The primary area of Professor Gorecki's scientific research has been the theory of dynamic systems. The first chapter in this issue is the paper written by professor W. Mitkowski entitled "Dynamical Properties of Metzler Systems" related to the similar works of Professor Gorecki. Analysis of dynamic systems has several viewpoints. However, one of the most important aspects of the analysis is discovery of the stability conditions. This special area of interest, evident in numerous scientific works by Professor Gorecki, is represented in this issue as a collection of four papers originated by the scientists from the Bialystok University of Technology. First and the most important in this section, is the paper by professor T. Kaczorek entitled "Practical Stability of Positive Fractional Discrete-time Linear Systems". Next, let me recommend to you two papers by professor M. Busłowicz: "Stability of Linear Continuous-time Fractional Order Systems with Delays of the Retarded Type" and "Simple Stability Conditions for Linear Positive Discrete-time Systems with Delays". Last but not least in this group is the paper written by doctor A. Ruszewski "Stability Regions of Closed Loop System with Time Delay Inertial Plant of Fractional Order and Fractional Order PI Controller". This paper, however, originates from the theory of stability of dynamical systems, but leads to practical applications of the theory in industrial stabilization problems.

Stability of dynamic systems is closely related to the concept of the system controllability. This area of interest is represented by professor J. Klamka's paper entitled "Constrained Controllability of Semilinear Systems with Delayed Controls". The paper is also related to yet another area of professor Gorecki scientific activities – the control of the dynamic systems with delays. The same area is represented in another paper entitled "Parallel Compensator Versus Smith Predictor for Control of the Plants with Delay" by professor R. Gessing. Selected problems of automatic control system are presented in papers "Applicational Possibilities of Nonparametric Estimation of Distribution Density for Control Engineering" and "Application of LMI for Design of Digital Control Systems" by professors P. Kulczycki and A. Krolikowski respectively.

Very special type of control problem is discussed by professor A. Świerniak in the paper "Direct and Indirect Control of Cancer Populations". Let me express here my own gratitude to professor Gorecki, who since 1971 has actively supported the expansion of the biocybernetic group (including my own research) in his Institute, although he personally was not engaged in this particular subarea of cybernetic and system theory.

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Dedicated to Professor Henryk Gorecki

Operational Research was another subarea supported by professor Gorecki. The paper "Queuing Systems and Networks. Models and Applications" by professor B. Filipowicz represents in this issue such branch of scientific activity of the Automatic Control Institute personnel under supervision and scientific patronage of professor Gorecki.

Research work performed in the Automatic Control Institute has been always firmly grounded in the mathematics. Professor Gorecki himself was not only famous automatic control engineer and extremely creative scientist in the area of system science. He has been also an outstanding mathematician, a member of the American Mathematical Society. The Institute led by professor Gorecki was a launching point for several excellent mathematicians. An example is professor S. Białas, who after work in professor Gorecki Institute, directed the Mathematical Institute, and became the first Dean of the Mathematical Faculty in the AGH University of Science and Technology. Therefore, it is no wonder that the article entitled "An Algorithm for the Calculation of the Minimal Polynomial" by professor Białas is also included in the presented issue.

Not only scientific research, but also didactic activities were the area of great attention by Professor Gorecki. New methods of teaching have been always promoted and developed in the Automatic Control Institute. This area of activity is a subject of two final papers: "Dependable and Certifiable Real-world Systems – Issue of Software Engineering Education" and "Selected Problems Resulting from the Use of Internet for Teaching Purposes" written by professors A. Kornecki and R. Tadeusiewicz respectively.

Obviously, the presented issue cannot include all the possible papers dedicated by the students and co-workers as a tribute to professor Gorecki. I hope, however, the selection of papers presented below shows how rich and multifaceted are the fruits of professor Gorecki professional activities.

Ryszard Tadeusiewicz

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Fig. 3. Henryk Górecki in Special Issue on "Dynamic Systems, Stability, Controllability, and Automatic Control", Bulletin of the Polish Academy of Sciences Technical Sciences, Vol.56, No.4, 2008
Source: http://bulletin.pan.pl/%2856-4%29misc.pdf

values of available forces, the limited power of steering signals, limitations of total available energy etc. The tasks of such type have a great practical amending as almost always when undertaking any task, we try to perform it maximally quickly, maximally effectively, maximally sparingly etc; it means the necessity of referring to the methods of optimal steering which we are able to create today owing, *inter alia*, the work of Professor Górecki.

After solving of the tasks, which could be come down to one established criterion: "mathematic talent", the restless spirit and creative imagination of Prof. Górecki began to seek for the successive challenges. Professor found them in the issues of **polyoptimization**. He dealt with it as one of the first persons in the 70ties and was involved in the mentioned problems until his death.

Polyoptimization differs from common optimization in the following: when we seek for the best steering, we must ensure the best values simultaneously for few independent criteria, which cannot have a joint index. So, if we want, for example, to maximize the economic effect of the conducted production and, at the same time, we want to minimize its ecological harmfulness, we have to deal with the task of multi-criteria optimization. In the tasks of such type, a lot of which we meet in our work (for example when undertaking political decisions), the traditional approaches and traditional methods occur to be completely unsuitable, so we must seek for the new methods and new solutions. Such was the work of Professor Górecki for many years. He gained also here the success and international recognition.

I mentioned here certain areas of the contemporary automation where Prof. Górecki made the extremely meaningful, creative contribution. They are not the sole scientific domains where we may find his successes. I would like also to add some examples, a priori informing that it won't be the complete list. Classical (dating back to the sixties) elaborations of Prof. Górecki concerning the assessment of extreme values of regulation errors in linear and non-linear control systems have permanently entered the canon of the knowledge in respect of the theory of control. His studies connected with the modern automation outlined (in the 80ties) one of the main directions of development, connected with the modern automation. Later on, in spite of being retired for 10 years, Professor Górecki did not give up scientific activities. His newest (very impressive!) deed was monograph:"Optimization and control of dynamic systems", published in 2006 and counting precisely 768 pages. The mentioned book is to be published also in English.

Apart from the personal research contribution to the development of automation, and especially theory of control, Prof. Górecki had also big merits in the field of **education of scientific staff**. He inspired his co-workers and numerous students to undertake new scientific problems. When guiding (for many years) the Centre of Doctoral at his Chair, Professor Górecki brought about to more than 100 doctoral dissertations, including 90 papers where he played a function of promoter. He did not leave his students later on, he guided them and inspired to further stages of scientific development. We may mention at least 30 papers for the scientific degree of habilitated doctor. The mentioned dissertations were developed owing to a big assistance of Professor Górecki. It is also worth mentioning ca. 10 professors (working at present in Poland) who owe their scientific development and scientific titles to scientific cooperation with Professor Górecki in a meaningful degree.

Fig. 4. Henryk Górecki during receiving the title of honoris causa of AGH, during the solemn meeting of the Senate of AHG, on November, 19, 1997
Source: https://historia.agh.edu.pl/wiki/Henryk_G%C3%83recki

These outstanding achievements in the field of education of the young scientific staff derive from four features of personality of Professor Górecki which I would like to emphasize and, in the context of the education of the staff, extremely highlight them. The first feature, necessary for gathering and inspiring such a great number of the students – is the enormous **knowledge** and research invention. Everybody who has a good luck to meet Professor Górecki in his scientific life did not go away with the empty hands. On the ground of his literature studies and comprehensive knowledge he was able to indicate the promising and interesting research area to everybody. Every interested person found the scientific areas which allowed him obtaining a scientific degree and, also, formed and shaped his scientific silhouette, often for the whole life. The second feature of the Professor's personality which brought such perfect results in the field of the staff education was His great friendliness to the people. Everyone who has a good luck to cooperate with the Professor was under the impression relating to the degree of identification of the Professor with the problems and needs of his co-workers. If the doctoral student had the troubles or the candidate for habilitation reached a dead-end, if the candidate for a scientific title was not able to evaluate whether his achievement is sufficient, it was enough to ask Professor for help and you obtained a good advice which was always effective as it was based on a profound wisdom of Pro-

Fig. 5. The text of laudation delivered by promoter of granting the degree of doctor honoris causa to Professor dr hab. Henryk Górecki, Eng., during the solemn meeting of the Senate of AGH, on November, 19, 1997, Informational Bulletin of the Employees of AGH
Source: https://www.academia.edu/35508125/Profesor_Henryk_G%C3%B3recki_wielki_uczony_niezwyk%C5%82a_osobowo%C5%9B%C4%87

fessor Górecki. The mentioned advice was so constructed that it could help a given person in the implementation of his ambitions and scientific aspirations to the greatest extent.

The mentioned already features of the Professor's personality included also his unbelievable intuition and knowledge of people. The decisions of Professor in respect of choosing the collaborators were always strikingly right, and His choice in respect of finding the performers for the specified research undertakings occurred to be – after many years – practically without exception, optimal. The persons entrusted with the solution of the specified scientific or organizational problems possessed, as a rule, the appropriate knowledge and talent as to deliver on the entrusted tasks with the profit for science and with the own success. The mentioned capability of optimal adjustment of the persons to the respective problems acted also in the case of Professor Górecki in the opposite side,. It means that it never occurred that he gave the task which exceeded the possibilities of a given person and brought about to his mental crisis and frustration. The scientific degrees and other successes under the care of Professor Górecki were obtained by the most talented students as well as by those who made up the lack of mind volatility with diligence and perseverance. Owing to skilful, extremely cultural and friendly attitude and behaviour of Professor Górecki, all His collaborators were able to make the contribution to development of science (each in his own way) as the instructed tasks corresponded to their possibilities. The extreme talent and intuition of professor Górecki allowed discovering the best from his pupils. It resulted in extremely abundant list of the persons whose scientific carried was developed owing to the initiative, enormous friendliness and care of Our Master. And, finally, the fourth feature of Professor which was most appreciated – His unchanging **constancy**. If he once has given us the confidence, He supported him permanently, reliably and with a full dedication. Each of us, the students of Professor, may remind at least one such event when the total scientific career, all achievements and the whole future were found questionable. During these difficult moments we obtained complete, decided and effective support of Our Master what allowed avoiding many misfortunes.

There is no doubt that the contribution of professor Górecki to Polish and international Automation is meaningful and, in certain areas, even outstanding, Also, it is not doubtful that he created Polish school of steering theory which is developing nowadays and has a numerous successes. It is also true that the Faculty of Electric Engineering, Automatics, Computer Science and Engineering in Biomedicine of Mining-Metallurgical University (AGH) in its present shape was shaped just owing to the work and, what is important, owing to right and far-reaching initiatives of Professor Górecki. Finally, it is evident fact that He promoted and shaped (in scientific aspect0 the record number of researchers who owe their total scientific carrier to the work and inspiration of Professor Górecki.

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Dr. hab. Tomasz Czekaj (Warsaw University of Life Sciences)
Dr hab. Karol Plesiński (University of Agricultural in Krakow, Poland)
Dr hab. Jacek Rechulicz (University of Life Sciences in Lublin, Poland)
Dr hab. Hanna Siwek (West Pomeranian University of Technology in Szczecin, Poland)
Dr hab. Adam Tański (West Pomeranian University of Technology in Szczecin, Poland)
Dr. Katarzyna Kotarska (Institute of Biotechnology of the Agricultural and Food Industry, National Research Institute)
Dr inż. Mateusz Malinowski, prof. URK (University of Agricultural in Krakow, Poland)
Dr Gabriel Minea (University of Bucharest, Romania)

Organizing Committee

Dr. Wacław Roman Strobel – Director of ITP-PIB
Dr. Kamila Mazur – Chairman of the Conference, ITP-PIB
Dr. Eng. Adam Brysiewicz – Deputy Chairman of the Committee, ITP-PIB
Dr. Eng. Kinga Borek – Secretary of the Committee, ITP-PIB
Dr. Eng. Tomasz Horaczek – ITP-PIB
Dr. Eng. Marek Hryniewicz – ITP-PIB
Dr. Eng. Anita Konieczna – ITP-PIB
Dr. Eng. Marek Kieronczyk – ITP-PIB
Dr. Eng. Dorota Kluszczyńska – Deputy Director for Development and Communication, ITP-PIB
Dr. Eng. Izabela Lubbe – ITP-PIB
Dr. Eng. Andrzej Seliga - ITP-PIB
Dr. Eng. Edyta Wrzesińska-Jędrusiak – ITP-PIB
Renata Kalinowska, MA – ITP-PIB
MSc. Bogdan Łochowski – ITP-PIB
Przemysław Trzosek, MSc – Deputy Director for Administrative Affairs – ITP-PIB
Jacek Zamielski, MA – ITP-PIB

Principal scientific topics of the Conference:

- development of technologies ensuring appropriate conditions for animals, low-emission and low-energy livestock construction, work safety, reduction of energy consumption and increasing production efficiency,
- renewable energy in rural areas, including the acquisition and management of agricultural biogas and methods of post-fermentation residue management, reduction of greenhouse gas and ammonia emissions from plant and animal production,
- sustainable agricultural production, circular economy with regard to environmental protection, organic farming, counteracting climate change,
- management of natural resources and soils, nature protection in rural areas, rational water management in drainage facilities, small water retention,
- water protection and ecology, water pollution and impact on biodiversity,
- water, sewage and waste management in rural areas;
- biotechnology and plant physiology in rural areas;
- innovative and smart agriculture.

The basic conference fee is PLN 1300, while for participants without a presentation, chapter in a monograph, and for PhD students, we provide discounts. The fee includes the costs of reviews of the articles provided by you, editorial work, printing, sending the monograph to the address provided by the Participants and providing on-line transmission. We encourage you to prepare an article in the form of a monograph chapter (20,000 characters), for which you are entitled to 20 points of the Ministry of Education and Science.

For all conference participants, the *Journal of Water of Land Development* magazine offers a 20% discount for the publication of the article (www.jwld.pl), with 100 points of the Ministry of Education and Science.

Deadlines:

Until August 16, 2023 – sending an application to the conference with an abstract
Until August 30, 2023 – payment
Until September 30, 2023 – submitting articles to the Journal of Water and Land Development
Until October 20, 2023 – submission of articles for the monograph.

The conference fee should be paid into account:
ALIOR BANK IBAN: PL 40 2490 0005 0000 4530 9244 4533
BIC/SWIFT: ALBPPLPW with the note: ITP conference and the name of the participant for whom the fee was paid.

XXIX International Scientific Conference will be held in
75th anniversary of the Institute of Construction, Mechanization and Electrification of Agriculture (IBMER)

and

70th anniversary of the Institute of Land Reclamation and Grasslands (IMUZ)
the merger of which created the Institute of Technology and Life Sciences – National Research Institute (ITP-PIB) in 2010

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„THE LEVER" FOR MEDISENSONIC

"DŹWIGNIA" DLA FIRMY MEDISENSONIC

DŹWIGNIA is granted always to one laureate, chosen by the Editorial Collegiums of Technical Review together with the Federation of Engineering Associations NOT and Publishing House SIGMA-NOT (the Publisher of *Polish Technical Review* and *Technical Review*). It is a prestige award, granted since 2000 to the entrepreneurs and managers for their effectiveness in the field of introducing the innovative solutions.

Fot. 1. Robert Gromada from MediSensonic S.A. takes the award from the hands of Ewa Mańkiewicz-Cudny (from the left), the President of FSNT-NOT and Magdalena Borek-Daruk, the President of SIGMA-NOT Publishing House (and, at the same time, Deputy Editor-in-Chief of Polish Technical Review),

This year, MediSensonic S.A., the company specialized in development of microwave and photo-optic technology, enabling safe and non-invasive medical and dental diagnostics has become the laureate of the mentioned above exceptional distinction. The discussed award was given to the co-founder and President of the company, Robert Gromada, on 30th May, during the XVIth Engineering Forum, organized together with the IXth Day of Mechanical Engineer. It was the event accompanying the International Fair ITM INDUSTRY EUROPE – Industry of Digital Era in Poznań.

When taking the mentioned award from the hands of Ewa Mańkiewicz-Cudny, the President of FSNT-NOT and Magdalena Borek-Daruk, the President of SIGMA-NOT Publishing House (and, at the same time, Deputy Editor-in-Chief of *Polish Technical Review*), the Laureate said that the LEVER was for him the exceptional symbol of technological progress. – *The distinction granted to us by engineers has a particular meaning for me because I am personally the representative of the mentioned profession. In the 40-person team, the engineers constitute the majority of the staff. They are outstanding electronic engineers, mechatronic engineers, mechanical engineers with scientific titles and, also the representatives of other specializations. We create together the innovative solutions for non-invasive medical and dental diagnosis. We deal with something which is invisible; microwaves and electronics. We try to overcome the microwave phenomenon, i.e. the waves which are invisible and we carry them in a form of radars and antennas on human body to make the precise measurements of life parameters in the continuous, permanent and non-invasive way.*

During 5 years of its functioning, the company has developed some extremely innovative technologies. The crucial medical devices of MediSensonic company include, *inter alia*, sensory mattress for detection of sleep apnoea (being dangerous for life), glucometer for non-invasive measurement of glucose level, pressure gauge for permanent illustration and monitoring of life functions and automatic scanner for diagnostics in oral cavity.

Developed by Jolanta Czudak-Tomaka
www.liderzyinnowacyjności.pl

MEETING OF ENGINEERING FORUM AND THE YOUNG CREATORS WITHIN THE FRAMES OF PANEL: "OFFER OF YOUNG SCIENTISTS FOR THE ECONOMY"

SPOTKANIE FORUM INŻYNIERSKIEGO Z MŁODYMI TWÓRCAMI W RAMACH PANELU PT. „OFERTA MŁODYCH NAUKOWCÓW DLA GOSPODARKI"

The mentioned meeting was oriented to young creators with the aim to present the good practices, possibilities and models. Another aim was to give the opportunity of listening to the young people opinions by the experienced, "old" creators, scientific and administrative workers and officials. Old – in quotation marks, of course, as it is not possible to specify the limit of the youth univocally.... You may feel young but be not classified into the group of the young generation, i.e. between the period of childhood and the mature life where you find your own way of life, start a family life, undertake the employment or organize a company, on the grounds of own ideas.

The guests of the panel were:

Łukasz Sztern – the Chief of Innovation Hub of Warsaw University of Technology, dealing in his everyday work with support of innovative solutions;

Łukasz Żrodowski – the president of start-up AMAZEMET, experienced innovator and author of many commercial patents;

Michał Cichowicz – activist of scientific circles and leader of innovative projects.

Each of the panellists represented a different range of experiences with which he is encountered every day. Their common feature included everyday youth and creativeness in developing or promoting the solutions.

The guests of the panels considered and discussed some important problems which they meet in quickly varying reality. The mentioned topics were as follows:

- New scientific ideas of the young people – chances and barriers in promoting the new solutions
- Interest and involvement of the institutions and enterprises in development of the young generation
- Creation of start-ups.

It is assumed that creativeness of the young man may be shaped at many moments during his maturation but the period of studies is the best time. The question arises: whether the universities give the appropriate possibilities for it? The panellists stated that after the years of demographic declines and peaks, we have entered the way of quite stable number of 19-years old people (although the present natural birth rate in Poland is one of the lowest in Europe). We have, however, at least stable, forecasted number of students for the coming years what may be documented by prognoses of GUS (Chief Statistical Bureau in Poland). The mentioned group will undoubtedly include the creators of new, perhaps crucial technological solutions. We should, however, think about the role of teacher in the contemporary world. It should be the person wise and abundant in knowledge but also, using modern tools of science and didactics. The role of the teacher in the era of artificial intelligence (AI) may consist in guiding the possible solutions and, also, asking the appropriate questions.

Being educated and "soaked" with the academic way of life, we do not notice sometimes that the companies and, especially, big enterprises construct their potential on innovativeness which is hermetically protected in their R & D departments. Sometimes the mentioned knowledge does not come to the universities, to the didactic domain, so the academic workers do not transfer this knowledge to their students. How, therefore, a young man is to get familiarised with the newest trends? Should he listen to the celebrities, seek for the proven authorities or perhaps ask GPT chat? How to reconcile these two realities?

We know that such as universities but also many state establishments support the initiatives of the young people. There are many available programmes for the financial support of the ideas for the new and innovative entrepreneurs. We know, however, that more and more foreign capital can be seen at the Polish market; they invest in the development of new ideas, being interesting in respect of business as well as technology.

Start-up – in the common understanding – is meant as a young, innovative company which seeks for its business model and tries to enter the market with a new product. To satisfy the definition of start-up, it must be a product which has not been at the market until now. Last year, the number of the registered start-ups was the highest (21%) in the Low Silesian voivodeship and the Mazovian voivodeship occupied the second place.

The team is the key factor in the development of the start-up. It gives a guarantee of success. A good team is able to verify quickly the idea, is open to the changes and is not afraid of the new ideas.

There is often made the reference to media statistics, stating that only 10% if start-ups makes a success. It means that 9 per 10 start-ups fail. The studies indicate that 21.5% start-ups are terminated with a failure in the first year, 30% – in the second year, 50% – in the fifth year and as much as 70% in the tenth year. What is the reason of such high percentage of unsuccessful projects? The start-ups fail due to financial reasons, most frequently at the moment when a product occurs to be unfit to the market needs, or requires time-consuming and expensive changes during its development, its technological debt increases, or the problems with the effective monetization appear. Running the company is a hard work. It is worthy to analyze the data e.g. Report Polish Start-up 2021.

Developed by Dawid Myszka

YOUNG INNOVATOR – GALA OF THE TALENTED YOUNG GENERATION

MŁODY INNOWATOR – GALA UTALENTOWANEJ MŁODZIEŻY

The approaching end of the school year was the occasion for summing up the initiatives of association movement, directed to a young generation. In Warsaw House of Engineer of NOT, the Gala summing up the 16th Competition "Young Innovator of 2020/2023 and the XLIXth Olympiad of Technical Science (15.06.2023) had place. The both mentioned initiatives were carried out under the patronage of the Minister of Education and Science.

The main heroes of the mentioned event were the laureates of the both initiatives – the young innovators from primary and secondary schools whose work was top rated by the Jury of the Competition and the pupils of the lyceums and secondary technical schools who coped the best with the requirements of the three-stage competition (the first school competitions were commenced in October 2022).

The Gala was also attended by the guests, including: Piotr Zakrzewski – Vice President of the Patent Office of Poland, Agnieszka Mokrogulska – Head of the Department of General Education and Programme Rudiments at the Ministry of Education and Science, Dr Remigiusz Kopoczek – Vice-President of the Research Network Łukasiewicz for research affairs, and, also the sponsors and donors: Jan Rosiński – The Chief Technologist in Toruń Plants of Sanitary Materials SA, Jan Koblak – the President of HORUS-ENERGIA company, Dr Maciej Wieloch – the President of the INFINI ASI company. There were also present the members of the Chief Committee of OWT with the chairman Prof. dr Stanislaw Wincenciak, Eng., and the members of the Jury of the Young Innovator, presided by Ewa Mańkiewicz-Cudny, the President of FSNT-NOT. Prof. *dr honoris causa* Czesław Waszkiewicz,Eng., the Chairman of the Jury of the competition *Numerus Primus inter Pares* was also the guest of the discussed ceremony. The summing up of this event had also place during the Gala. The Gala was also attended by the teachers, patrons, parents of the laureates and by the representatives of association movements, their agendas (Publishing House SIGMA-NOT) and the Regional Organizational Units, owing to which it was possible to run the competition and the Olympiad.

Fot. 1. Laureates and guests during Gala Young Innovator and Olympiad of Technical Science

Fot. 2. The guests and laureates were greeted by the President of FSNT-NOT, Ewa Mańkiewicz-Cudny

Fot. 3. Barbara Hoffman (the education inspector of the Mazovian Board of Education) reads out the congratulation letter of Przemysław Czarnek, the Minister of Education and Science

After greeting the participants, Gala was opened by a short appearance of Ewa Mańkiewicz-Cudny, the President of FSNT-NOT. Madame the President referred to the lasting celebrations of the Year of Mikołaj Kopernik and also, mentioned Maria Skłodowska-Curie as the persons who may be, even today, the role models to be followed for the young people. Then, Piotr Zakrzewski, Vice-President of UP RP invited the laureates to a great journey during which is will be worthy to watch the world, to get familiarized with it but also, to make it perfect and changed.

The congratulation letter of Przemysław Czarnek, the Minister of Education and Science to organizers and laureates of the both discussed initiatives was read out by Barbara Hoffman, the education inspector of the Mazovian Board of Education.

After the official part of the ceremony Mr Janusz M. Kowalski, the host of the Gala read out the protocol of the Jury of the Competition: "Young Innovator", which evaluated the received pieces of work and chose the laureates in three categories: primary school, lyceums, and technical schools. The first places were granted to the following persons:

- Antoni Jędraszak from Primary School in Wierzonka, for the project: "Filament device – PetMake" (transformation of PET bottle into filament in printer), prepared under the guidance of Ewelina Tyranowska, M.A.;
- Jerzy Grabowski from the Secondary School - School of Leaders in Warsaw and Samuel Wiench from the Salvatore Dali Secondary School in Warsaw, for the project "Car lifting device – educational set for learning of mechatronics and programming", prepared under the guidance of Engineer Arkadiusz Kwapisz, M.Sc.;
- Filip Kiełbowicz, Mateusz Żuk and Łukasz Pytlowany from the Stefan Banach Technical School no 2 in Jarosław, for the project "SEMPER – device for rehabilitation of ankle joint", prepared under the guidance of Engineer Mariusz Skupień, MSc., and Engineer Bartosz Nycz, M.Sc.

It is worthy to mention that the President of FSNT-NOT granted also a Special Award. Its laureates became Tymoteusz Więckowski and Maurycy Mówiński from the Adam Mickiewicz Primary School no 4 in Kwidzyń for the project :"Cloth with the built-in system of warming up the pet – WARM DOG", prepared under the guidance of Izabela Gąsiorowska, M.A.

Awards and diplomas were handed to the laureates and their patrons jointly by the President Ewa Mańkiewicz-Cudny,

Fot. 4. Laureates of the Competition "Young Innovator"

Agnieszka Mokrogulska – The Manager at Ministry of Education and Sciences and by Jan Rosiński, Technologist in TZMO (Toruń Manufacturing Plant of Dressing Materials) in Toruń.

At the end of this part of the ceremony, Prof. Michał Szota, the President of the Association of Polish Inventors and Rationalisers, co-organiser of the Competition Young Innovator, handed the Distinction of the Association which was granted to Paweł Komasara and Piotr Seremak from the AK "Jędrusie" Guerrilla Unit Complex of Schools in Połaniec for the project: "System improving the safety of the passengers in vehicles during stop – as saving often human life", guided by Engineer Mariusz Zyngier, M.Sc.

Developed by Janusz M. Kowalski

LAUREATES OF THE XLIXTH OLYMPIAD OF TECHNICAL KNOWLEDGE

LAUREACI XLIX OLIMPIADY WIEDZY TECHNICZNEJ

The appearance of Prof. dr hab. Stanislaw Wincenciak, Eng., the Chairman of the Chief Committee of OTK commenced the distinguishing of the laureates of the XLIXth Olympiad of Technical Knowledge.

We should stress here the success of the first place winners. They were: in mechanics-construction group – Ludwik Madej from the King Kazimierz the Great Lyceum no 1 in Olkusz, whose guide was Maria Piasny, M.Sc.; in electric-electronic group – Kacper Chałubek from the Complex of secondary schools in Kleszczew, with the school caregiver Engineer Artur Szczęsny, MSc.

Diplomas and awards for the laureates and their patrons were handed jointly by the President Ewa Mańkiewicz-Cudny, Prof. Stanisław Wincenciak, Piotr Zakrzewski – Patent Office of RP and Jan Koblak – the President of Horus-Energy enterprise.

The ceremony was ended by the appearance of Dr Remigiusz Kopoczek, the Vice-President of the Research Network Łukasiewicz, who made an interesting presentation addressed to the young laureates.

After this address, the host of the total event expressed the words of gratitude to the Ministry of Education and Science and to the partners, sponsors and donors of the Competition and of the Olympiad: Foundation PKO Bank Polski, Toruń Manufacturing Plant of Dressing Materials SA,, Adamed Foundation, the Research Network Łukasiewicz,, companies: Horus-Energia, Stern Weber, MZGOK Konin, Hydroimega, INFINI ASI, Warsaw House of Engineer and Publishing House SIGMA-NOT and NOT- Computer science. The specials thanks were given to the

Fot. Laureates of the XLIXth Olympiad of Technical Knowledge

Fot. Words of gratitude paid to the partners, sponsors and donors of the Competition and the Olympiad

Military University of Technology for several-times organized chief competition of the Olympiad.

There were also expressed the words of appreciation to the Regional Organizational Units of NOT which participated also in organization of the Competition and of the Olympiad, and to the universities and schools which organized the competition of the second degree of the Olympiad.

Gala was ended with the joint pictures and a small party.

Developed by Janusz M. Kowalski

NUMERUS PRIMUS INTER PARES

NUMERUS PRIMUS INTER PARES

Traditionally, during the Gala, summing up the initiatives of the association activities directed to the young generation – the competition Young Innovator and Olympic Competition of Technical Knowledge – the summing up of the 36th Competition *Numerus Primus inter Pares* was held.

The purpose of the mentioned competition, organized by the Society of Culture and History of Engineering is to select the best periodicals in the field of popularization of technical knowledge and culture and popular-technical journals from the previous calendar year.

This year's edition of the Competition was participated by 7 publishing houses, applying 11 titles in total. The Jury of the Competition, as acting under the presidency of Prof. Czesław Waszkiewicz, PhD., Eng., has evaluated highly the professional and graphic level and the editorial form of the sent periodicals. The Jury granted the following titles of laureates:

In the group of the periodicals, popularizing science and engineering – the title of laureate: Numerus Primus inter Pares was given to no. 10/2022 of journal: "Energetics. Problems of energetics and fuel-energetics management"; publisher: COSiW SEP.

In the mentioned category, the Jury granted two distinctions: to journal "Advisor, the Małopolska Agricultural Informer", no.5-6/2022, publisher: The Małopolski Agricultural Advisory Centre Karniowice and to periodical "Agro Profile", no. /2022, publisher: Agro Publishing House Ltd., Suchy Las.

In the group of specialist periodicals – the title of laureate: *Numerus Primus inter Pares* was granted to **no. 8/2022 of "Meat Industry"**, publisher: SIGMA-NOT Ltd., and the distinction was given to "Electro.Info", no.4/2022, publisher: MEDIUM Group

The Cups and diplomas were jointly handed to the representatives of the distinguished editorial offices by the President of the Jury of the Competition, Prof. dr Czesław Waszkiewicz, Eng., *doctor honoris causa* and the secretary of TKiHT, Janusz M. Kowalski, MSc.

Fot. Katarzyna Przybytniak-Marzec (Head of Advertisement and Marketing Department at Publishing House SIGMA-NOT) collects the Cup of Numerus Primus inter Pares on behalf of the editorial office of journal "Meat Industry"

Developed by
Janusz M. Kowalski

InterNanoPoland 2023

11th - 12 th October, 2023

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