Załącznik 2b – wersja ENG

Krakow, July 16th 2018

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SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

concerning research and scientific, teaching and organizational activities

I. Name and surname

Grzegorz Kiesiewicz

II. Diplomas, degrees – with the name and place of obtaining, year of graduation and the title of doctor's thesis

Doctor of Technical Sciences (graduated with honours):

Field of study:	Metallurgy,
Specialization:	Metal Forming,
Thesis title:	"Theoretical and experimental analysis of contact wire drawing process with the use dies made from synthetic polycrystalline diamond",
Date of defence:	October 22nd 2013,
Place of defence:	AGH University of Science and Technology in Krakow, Faculty of Non-ferrous Metals,
Thesis supervisor:	prof. dr. hab. eng. Tadeusz Knych,
Thesis reviewers:	prof. dr. hab. eng. Józef Zasadziński, prof. dr. hab. eng. Jan Pilarczyk.

Master of Science:

Field of study:	Metallurgy,
Specialization:	Metal Forming,
Thesis title:	"Research on production technology of contact wires made from oxygen free copper with addition of silver, obtained from UPCAST line",
Date of defence:	July 10th 2008,
Place of defence:	AGH University of Science and Technology in Krakow, Faculty of Non-ferrous Metals,
Thesis supervisor:	prof. dr. hab. eng. Tadeusz Knych.

III. Information on employment in research facilities

November 24th 2017 – currently: **Assistant professor**,
AGH University of Science and Technology, Faculty of Non-ferrous Metals, Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals, Mickiewicza 30 Av., 30-059 Krakow.

September 24th 2013 – November 24th 2017: **Assistant**,
AGH University of Science and Technology, Faculty of Non-ferrous Metals, Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals, Mickiewicza 30 Av., 30-059 Krakow.

IV. **Indication of the achievement resulting from art. 16 sec. 2 of the Act from March 14th 2003 on academic degrees and academic titles (Dz. U. 2016 r. poz. 882 ze zm. w Dz. U. z 2016 r. poz. 1311.):**

a) Title of scientific achievement:

Habilitation monograph „Modern catenary system for overhead railway traction"

b) Author/authors, title/titles of publications, year of publication, name of the publisher, publishing reviewers:

Author:	Grzegorz Kiesiewicz,
Title of publication:	„Modern catenary system for overhead railway traction",
Year of publication:	2018.,
Name of the publisher:	Oficyna Wydawnicza "Impuls",
Publishing reviewers:	prof. dr. hab. eng. Jan Pilarczyk, dr. hab. eng. Paweł Kwaśniewski.

c) Discussing of the scientific objective of the aforementioned paper work and results achieved, along with a discussion concerning their possible use

The subject of the monograph mentioned above, which is the main scientific achievement in the habilitation procedure concerning myself, focuses on the comprehensive design, production, testing and implementation of the original structural solution i.e. the modern overhead traction catenary system, which is dedicated to the conditions and characteristics of the Polish traction market with the possibility of its use abroad. Such wide approach to the research and both constructional and technological problems resulted directly from the demand of domestic market, where there is a lack of modern competitive solutions, and currently used constructions are dated back several decades. The implementation of the assumed and presented above objectives required to prepare a complex plan for its realization, which in the first stage were focused on a detailed, global state of the art analysis, as well as theoretical and laboratory research on existing solutions of catenary systems. Subsequently, a series of design studies were started in order to enable the first concept of a new type of solution to be proposed. In the course of the conducted research, the technological properties of various types of construction materials, based on 6xxx aluminum alloys, were analysed in terms of their possible use for the production of individual components in new catenary system. Next development of a new general design of construction, new geometry of the main profile and a new joining system allowed to develop the final design of a new type of railway catenary system. In the next stage of the work, the production technology of all system components was designed and tested, which enabled to make the first prototype and to test it in laboratory conditions afterwards. Positive results of these tests confirmed the high mechanical strength of the construction and enabled the commencement of field testing, which was carried out in two stages, using the experimental track infrastructure in Żmigród (as the only facility of this type in Poland) and in real conditions on the Daleszewo - Szczecin Podjuchy railway route, where designed system worked under railway traffic (both passenger and freight) for one year. The completion of above mentioned field testing stage enabled, in the final stage of the works presented in the monograph, to obtain in September of 2017 the admission of the designed catenary system for general use (and thus sales) within the Polish railway infrastructure.

Considering the obtained and presented in the monograph results, I would like to start to discuss them chronologically from theoretical and experimental research on classical railway catenary systems, which are currently widely used on a large scale in Poland. These constructions, in the generally accepted basic scheme of railway traction, are responsible for sustaining the mass of the overhead traction line system, which in its essence is an assembly of wires allowing to supply the electric power to railway vehicles. Electrical energy transfer is realised directly through the sliding contact of the contact wire with the contact strip of the locomotive's pantograph. The catenary system itself is fixed at a strictly defined height to the so-called poles/masts and traction gates and, as an extremely important indirect element, also allows to shift the supporting structure from the so-called railway gauge. Thanks to this, it is possible to set the overhead traction line directly above the railroad track axis, ensuring that there is no collision between supporting structures and passing trains. Due to the direct contact of the catenary system with the contact wire, which carries high voltage, it must be also electrically insulated from the support construction (and thus from the ground) by means of the so-called traction insulators. The traditional and currently used structural solution for catenary systems is based on a multi-element, steel pipe structure with a stay rope. This solution is characterized by a large number of components (about 12 main components) and hence a large number of screw connections, which in practice results in mounting difficulties and difficulties associated with periodic need to adjust the overhead traction line and thus the need to adjust the position of individual catenary system components.

In order to estimate the mechanical strength in this type of structure, a numerical analysis of the traditional version of the catenary system was carried out using the Finite Element Method (abbreviated as FEM) and the ANSYS Mechanical software, taking into account detailed PKP guidelines regarding the load scheme for this type of construction, which was included in the normative document PKP let-110. Direct comparison of the results obtained from these analyses showed that in both applied load schemes, the traditional support structure, which in the subsequent part of the work was a reference for a new type of catenary system, is strongly uneven. In some areas (e.g. at the handle of the stay arm or at the bottom mount of the traction insulator) obtained stress values approach, or even exceed, the yield point of the metal from which it is made. Furthermore in other areas the structure was strongly undersized and obtained stress values were close to zero. Next on the basis of the numerical analysis results and results of exploitational properties obtained in laboratory tests of structural elements, a guidelines for designing a new type of structure were developed in cooperation with the research staff of the Railway Institute and employees of PKP Polskie Linie Kolejowe S.A. These guidelines assumed that designed catenary system must ensure appropriate construction parameters of the overhead railway system and should be characterized by full functionality and compatibility of the application due to its intended use as a replacement for existing solutions of traditional systems and be also characterized by:

- high corrosion resistance (optimum working time of at least 30 years) demonstrated in simulation tests in a salt spray chamber with exposure time of at least 336 hours, based on the absence of significant corrosion defects on the metal surface,
- relaxation level of clamping forces of screw joints below 8% in the 24 h test
(in selected, less-responsible elements, maximum of 10% is allowed),
- lack of sliding effect between structural elements and the lack of slipping of the entire catenary system relatively to supporting structures, under the influence of various operational loads occurring in the overhead contact line,
- pulling force of elements transferring the tension of overhead traction line system at the level of min. 30% greater than the assumed nominal force (taking into account the safety factor coefficients for a given element),
- simplicity of assembly (minimization of the number and types of screw connections used),
- low mass (lower mass in relation to currently used solutions),
- high aesthetics.

In order to develop the concept of a new catenary system it was necessary to carry out a detailed state of the art literature analysis, which primarily were concentrated on the history, development and operation principles of various types of global catenary system solutions. This analysis was based on the available scientific literature, patent knowledge and catalogue sheets. Conducted analysis allowed to fully understand both the oldest solutions bearing the features of the currently used construction, which are dated back to 1935 (Patent DE 608282 C) and 1938 (Patent DE 658973 C) as well as modern foreign solutions dedicated to railway transport, taking into account the so-called high speed lines. These solutions include patented in 2012, the OMNIA system, which was implemented for sale by the BONOMI concern and the catenary system patented in 2016 which is owned by the international ALSTOM concern. It is worth emphasizing that all examples of modern railway catenary systems for overhead traction line systems, which were analysed and described in details in the monograph, were designed for specific power systems. Most often, in the case of newest solutions, they were designed for AC 15 or 25 kV systems, taking into account the local economic conditions of a given country (or countries) in which they were to be used. In the case of domestic solutions, based on a DC 3 kV power supply system, it turned out that there are no examples of modern solutions for catenary systems, which along with the previously developed guidelines created the basis for undertaking the research and development project aiming for a new type of catenary system solution, which will be designed in accordance with the domestic users requirements, also concerning their financial aspect.

The newly developed concept of the new catenary system assumed total modification of the currently used in Poland solutions and their individual components. A main supporting profile was introduced, located in a horizontal plane, parallel to the supporting structure. This element needed to be designed in a way to transfer the loads existing in the railway traction, related to the mass of the overhead traction line and the dynamics of the system during cyclic crossings of various types of trains (network vibrations, air pressure, etc.). Next it was determined that the main profile will be fitted with a messenger wire holder bracket (above the main horizontal profile) and a registration arm bracket which will be located below the main profile. Additionally, in order to increase the stiffness of the entire construction and to limit its final mass, a stay rope from the mast to the main profile was included.

Thanks to this solution, it was possible to reduce the external dimensions of the main profile and thereby significantly reduce the mass of entire system.

Another extremely important stage in the designing process of the new type of catenary system were research regarding the selection of the right type of structural material, which would be used to manufacture its individual components. At the stage of developing the guidelines it was already initially assumed that this material will be a selected from the wide range of high-strength aluminum alloys. Nevertheless finally chosen material must have been characterized by a wide range of technological properties enabling its practical use in the production of modern catenary system components. Based on the performed analysis and internal detailed discussion, it was determined that the target research will be conducted on two 6xxx series alloys, namely the EN AW-6060 alloy in the T66 state and EN AW-6082 in the T6 state. Both materials were subjected to the analysis of selected mechanical and technological properties, which made it possible to assess the suitability of their use in further construction works. In particular, the work carried out included the literature analysis of the basic properties of both materials and laboratory tests verifying these data. Next research on welding of the selected aluminum alloys were performed and followed by stress relaxation tests, deformability tests (in bending, flattening and expanding of tubes and also during die forging) and in the Erichsen trial. The entirety of research works allowed to decide that the target material for the production of the main components of the new catenary system will be EN AW-6082 in the T6 state. As it turned out, this material has higher mechanical properties both in the solid state and after the welding process, which should ensure the designed construction to have a higher level of mechanical properties. The research on deformability showed that unfortunately in comparison to the EN AW-6060 T66 alloy, this material is characterized with a lower level of deformability, but when using a favourable stress scheme (optimally triaxial compression) in hot metal forming processes such as forging or extrusion, the reserve of its plasticity should be sufficient even to make elements with complicated, multi-coherent geometry. Additionally, based on the performed set of tests, it was assumed that the smaller elements of the designed system can also be made from stainless steel in 1.4301 grade which is a material with high corrosion resistance and high level of mechanical properties.

The selection of the right type of material allowed to move forward to the next step which was to start the design and numerical research on the development of the optimal geometry of the newly designed construction. These tests were initially carried out for the predetermined geometry of the main profile and a pre-selected general construction of the catenary system, which took into account the attachment of the stay rope directly to the main profile. The detailed numerical analysis of the model with the use of finite element method allowed to observe that moving the place of stay rope attachment from the main profile to the messenger wire holder bracket resulted into a significant increase in the stiffness of the entire system, which was confirmed by an additional series of numerical tests. The firstly developed geometries of the main profile were designed in order to allow them to be connected with each other and at the same time prevent rotation of the joined elements. In the developed concepts this was ensured by the use of grooves on both sides of the profile, which in the initial stages of the conducted work were formed in the shape of a rectangle. As part of subsequent works and analyses, it was finally decided that this grooves should have a "T" shape. Use of this kind of clamping in the holders, in addition to prevent the joints from rotating around, should also at the same time ensure the possibility of their position adjustment on the main profile. The conceptual geometry of the main profile was based on a rectangular shape with rounded corners. The profile's height was initially set at 110 mm and the width was 70 mm. The radius of the corners of the rectangle was 5 mm. In the geometry of the profile, two "T" shaped grooves have been cut symmetrically, working as guide rails for the holders of the catenary system. Inside the profile, 3 crossbars with a thickness of 3 mm were designed, all running from the inside to its external walls. In the centre of the profile, a circle with a diameter of 24 mm was cut out. At this stage, this conceptual geometry of the main profile taken into account some of the basic assumptions concerning, among others, its general dimensions or the way of joining it with other elements of the designed system. Continuing research works, in the next step main profile geometry had to be optimized from the point of view of its mechanical properties and mass ratio, which was performed using the ANSYS software and FEM method. The range of designed types of multi-coherent geometry of the main profile included several types, taking into account various modifications of the previously developed general geometry and their dimensions. For all developed models, exactly the same boundary conditions were used in FEM analysis, i.e. mainly the load scheme, the finite element mesh density and the properties of the material models. The obtained test results and their further analysis allowed to develop the final concept of the cross-section of the main profile, which possessed the optimal ratio of its mass and mechanical properties.

As part of further design works, three innovative versions of joining system for main structural elements were also developed, out of which the most promising was the one consisting of two elements reflecting the external geometry of the main profile. Both sides of the joining system should be next folded together and attached to the holder by welding, leaving a partial gap in the middle of two permanently connected parts. Determination of the exact position of holders in this case was based on gap tightening with two screws located in the upper part of the system. Such solution, comparing to the other analysed versions of joining systems, was characterized mainly by a high level of functional properties in the form of assembly simplicity and ease of adjustment of the system and the fact that the entire joining assembly will be combined with the brackets of both, the messenger wire holder and registration arm holder forming one element, allowing to simplify the construction of the catenary system. The target geometry of the grip has been optimized based on the results of numerical simulations.

As part of the final stage of design research works, a final model of a new type of catenary system was developed, taking into account all of its most important components, i.e. main profile, joining system, joints, traction insulators and individual screw connections. This model was subjected to a final analysis with the use pf finite element method according to the requirements of PKP, showing unambiguously that the structure was designed adequately to the requirements imposed on it.

The new version of the overhead traction line catenary system designed from scratch required the development of a detailed technology for the production of all its components. Depending on the complexity of the individual elements and the material from which they were made, the selected technological processes had to allows obtaining products with high quality, both internal and surface. Also what is equally important due to the commercial nature of the system, its production technology had to have adequate efficiency and at the same time, had to be characterized by the lowest possible production costs. It is worth mentioning that already in the stage of initial design works on new catenary system, most constructions have been developed in order to allow the use of specific production technologies, which definitely increased the possibility of their later use in the commercial solution. As part of the works carried out and presented in the monograph, the final technology was designed for the production of the main profile and joining system based on the process of direct extrusion of the EN AW-6082 alloy and its following thermal treatment to the T6 state. In the case of the majority of other elements, i.e. for a messenger wire holder, registration arm holder, catenary system mounts, registration arms and stay rope, the applied technologies were based mainly on bending and machining processes of stainless steel in 1.4301 grade. Only in the case of the the traction insulator joint, due to its complicated geometry, it was decided to use the EN AW-6082 alloy and the die casting process, following heat treatment and finishing mechanical machining of the cast. Produced components of the railway catenary system were next subjected to detailed laboratory tests allowing to estimate their exploitational properties in the next course of work. These tests included analysis of mechanical properties of holder brackets welds, testing the mechanical properties of the stay arm and joint of the insulator, testing the pulling force of the catenary system grips, testing stress relaxation of screw joints and testing the corrosion resistance of selected system components in the salt spray chamber. The results obtained during above mentioned research works allowed to verify the correctness of previously prepared design and production technology and, when it was necessary, for the optimization of their construction, which further enabled the assembly of the first functional prototype of the new catenary system and subjecting it, as a whole, to further laboratory and field tests

For the first laboratory effort tests, a version of catenary system with the farthest possible position of the contact wire from the front of the support construction was selected, under which, due to the applied moments of forces, the highest values of stresses and strains were supposed to occur. These tests included measuring of the construction stress and strain state with the use of electric resistance wire strain gauges, taking into account the temperature influence on the measured values. Altogether, 9 active and 9 compensating strain gauges were installed, the location of which resulted from numerical analyses carried out previously, i.e. the occurrence of areas with the highest stress values in the construction. Then all components prepared for testing were joined together and attached to the catenary construction model, thus enabling the prototype of the new catenary system to be made. The load scheme used in the presented bench tests was in line with the previously adopted guidelines. The results of the tests showed that the new design of the catenary system was weighted in a safe way. Direct comparison of the obtained test results with the yield strength values for the aluminum alloy EN AW-6082 in the T6 state and stainless steel in the 1.4301 grade also allowed to state that the required safety factor of the construction at the level of approximately 3, meeting the PKP requirements. The catenary system was next subjected for further testing in the field conditions at the Railway Institute test track and on the real traction line with actual movement of railway vehicles. Both of these tests were completed on September 22nd 2017, which allowed to clearly demonstrate that the modern catenary system (designed from scratch) meets all the requirements of the manager of the national railway network PKP Polskie Linie Kolejowe S.A.. Above mentioned allowed to obtain admission of the catenary system which is required for its commercialization and use in Polish railway lines.

The newly developed, tested and approved by PKP construction of the railway overhead line catenary system has a number of benefits compared to traditional solutions which are now widely used, resulting both from the use of new geometry and a new type of material from which it was made of. In particular, it should be noted that the new catenary system is characterized by more than a half lower mass and fewer number of components and tools necessary to assembly it. Ultimately, this means a shorter installation time in the range of 30 to 50% compared to currently used constructions. Bearing in mind the high level of innovation of the developed solution and the current market demand for this type of products (both in Poland and abroad), a procedure has been carried out that allows the new solution of the catenary system to be protected in terms of intellectual property rights. In order to do so, a patent application was filled under the title “Set up for suspension of electrical traction cables, especially for railway, tramway and/or for subway use” and OHIM EU industrial design application under the title “Cantilever for electrical traction cables”.

It should be also noted that some of the issues discussed above and presented in the habilitation monograph were carried out by research team consisting not only of myself, but also other scientists from the Non-Ferrous Metals Faculty at AGH and also constructors, engineers and technologists from the MABO company with the substantive support of experts from the Railway Institute from Warsaw. Taking all of above mentioned research results into account, it allowed me to include in the monograph the most important aspects related to the design, implementation and research of the construction solution in question, and not only to present the results of my own research within the discussed subject matter, which in my opinion would significantly reduce the scientific and technological value of the submitted monograph.

In conclusion, taking all of the above into consideration, author states that submitted monograph and the issues raised in it is fulfilling the requirements for the qualifications of the scientific staff for proceedings for granting the habilitation degree via completing the original design, construction and technological achievement (mentioned in point 2 of art. 16 sec. 2 of the Act from March 14th 2003 on academic degrees and academic titles (Dz. U. 2016 r. poz. 882 ze zm. w Dz. U. z 2016 r. poz. 1311.)), concerning a modern system of railway catenary system, dedicated mainly to the local conditions of the Polish railway infrastructure, while ensuring the possibility of its use outside the borders of Poland. It is also recognized that the monograph has a significant contribution to the development of metallurgy field through scientific and technological route designed and described by the author in the monograph allowing the first of its kind (and in this scale) application of high-strength aluminum alloys in applications related to the railway overhead traction line network. In particular, the development of the above complex technology of designing a new catenary system takes into account stages such as:

- methodology for developing the requirements and guidelines that form the basis for following design works,
- selection of a suitable construction material to use in the designed construction, which requires the determination of its mechanical, plastic and exploitational properties, taking into account previously developed requirements,
- the process of concept and geometry design of individual catenary system elements and the structure as a whole and their inter-operational and final tests performed with the use of finite element method,
- selection of appropriate technological processes for the production of designed elements and testing their operational properties which enables to obtain the final technology for the production of the catenary system,

- bench and ground testing of a new type of structure, taking into account the its actual working conditions,
- admission of the designed and constructed structure for the use and sale on the basis of previously conducted bench and ground tests.

In particular, the contribution of the monograph author into the development of a modern catenary system dedicated for the overhead traction line is:

- literature analysis of previous solutions of catenary systems (chapter 1), where the author himself discussed the construction of traditional railway overhead traction line catenary systems as well as patent and literature analysis of available worldwide solutions for catenary systems and individually performed numerical analysis of traditional railway catenary system in order to verify its mechanical properties. In addition, in cooperation with other scientists from the Non-Ferrous Metals Faculty at AGH, author conducted research on selected operating properties of the components of the catenary system. Then in cooperation (consultations) with the academic staff of the Railway Institute and employees of PKP Polskie Linie Kolejowe S.A. author developed the guidelines for designing of a new type of catenary system.

- the design of a new railway overhead traction line catenary system (chapter 2) took into account the author's wide involvement in issues related to developing the concept of a new catenary system, selection and testing of exploitational properties of selected construction materials in cooperation with specialists from AGH, MABO company and the Railway Institute. Also in this chapter author individually conducted research on the development of general construction of the catenary system, research on the development of the cross-section geometry of the main profile, research on the development of a joining system and fixing of load carrying profiles, as well as design and numerical testing of the final version of the catenary system model,

- development of production technology and laboratory tests of the new railway overhead traction catenary system (chapter 3), which in particular concerned the production technology of the main profile and joining system profile and also other elements of designed catenary system as well as laboratory tests of its individual elements and bench tests of the new catenary system prototype. These studies were carried out under the supervision and with the active participation of the author in cooperation with the scientists from AGH and technologists form MABO company and in consultation with specialists from the Railway Institute,

- field testing of the railway overhead traction line catenary system (chapter 4), where the author actively participated in the completed research works on the catenary system in static and dynamic conditions which was done on the experimental track in Żmigród.

V. Discussion on other scientific, teaching and organizational achievements

Historically, my scientific work began during the fourth year of master's studies at the Faculty of Non-Ferrous Metals at AGH University of Science and Technology in Krakow with the specialization of metal forming processes and at that time it was oriented mainly on the research concerning the production technology of contact wires made in the UPCAST line out of oxygen free copper with the addition of silver. These tests were planned in order to verify the possibility to use (from the mechanical properties and surface quality point of view) copper wire rods with diameters above 20 mm for cold drawing of contact wires. The research results obtained as part of the work that formed the basis of my master's thesis confirmed that this technology can be successfully used in industrial conditions, which allowed its subsequent implementation in the cable plant TELE-FONIKA Kable S.A. As one can see, from the first planned and completed research the main area of my interest was to develop new types of materials and processing technologies for practical applications in the generally understood subject of railway transport, specifically in the area of railway overhead traction line network.

I have officially finished my master's studies on July 10th 2008 after defending my thesis entitled "Research on the production technology of contact wires made of oxygen free copper with the addition of silver, from the UPCAST® line", which was supervised by prof. dr hab. eng. Tadeusz Knych, who is currently the dean of the Faculty of Non-Ferrous Metals at AGH. On this basis I obtained the Master of Engineering academic degree in the field of metallurgy, which subsequently allowed me to start doctoral studies on October 1st 2008 at the Faculty of Non-Ferrous Metals, also with the scientific supervision of Professor Tadeusz Knych. Continuing the subject of my master's thesis, I started to carry on research works concerning the theoretical and experimental analysis of the contact wires drawing process using polycrystalline synthetic diamond dies. This analysis was conducted in order to increase final mechanical properties of contact wires by reducing the temperature of deformed metal in the industrial drawing process. Apart from the above-mentioned applicational goal, these studies also had a very interesting scientific aspect, i.e. a theoretical analysis of the metal plastic state in the complicated, non-circular geometry of contact wire die approach angle. Detailed and complex literature analysis did not allow to find any examples of this type of research and the review of all available methods, which allow to formulate the problem of metal plasticity, enabled to select the finite element method as the optimal one for the analysis of raised problem. In addition, numerical tests made it possible to obtain metal stress and strain characteristics as well as to estimate the unit pressures between the surface of deformed metal and the surface of the inner walls of the die. The entirety of the above described and completed research and its further analysis allowed me to elaborate a doctoral dissertation and thus on October 22nd 2013, after defending its subject matter in front of the council of the Faculty of Non-Ferrous Metals and gathered guests, to graduate with honours and obtain the academic title of Doctor of Technical Sciences in the field of metallurgy. In the meantime, on October 24th 2013, I was employed as an assistant to work at the Faculty of Non-Ferrous Metals at AGH. At this time my scientific achievements included co-authorship in 36 publications in scientific and industrial journals as well as in conference publications, both domestic and international. Especially worth mentioning is my participation as a main project developer in ten research and targeted projects. One of the direct effect of my scientific activities before obtaining the Doctor of Technical Sciences degree was co-authorship in seven patent applications in Poland and eight industrial designs of OHIM binding in the EU.

After obtaining the Doctor of Technical Sciences degree up to this day (June 2018) I continued my scientific and research work, the effects of which are closely related to my scientific achievements. Detailed list of all my scientific achievements is included in attachment 3 to the habilitation proceedings application. The following is also a synthetic summary covering the most important, in my opinion, scientific and research as well as teaching and organizational achievements included in above mentioned attachment.

Synthetic summary of scientific achievements after obtaining the Doctor of Technical Sciences degree (November 2013 - June 2018):

- monograph - 1,
- publications in domestic and international scientific journals - 44,
- presentations at domestic and international conferences - 9,
- co-authorship in papers presented at domestic and international conferences - 28,
- completed original design, structural and technological achievements - 11,
- obtained domestic and international patents (co-authorship) - 14,
- obtained domestic and international utility models (co-authorship) - 15,
- domestic patent applications of inventions and utility models (co-authorship) - 10,
- manager of research, development and implementation projects - 4,
- participation in domestic and international projects (main developer and developer) - 13,
- head of commissioned work and expert opinions - 5,
- main developer of commissioned work - 7,
- participation in expert teams - 3,
- assistant supervisor of doctoral dissertations - 2,
- scientific supervision over students (supervisor of engineering and master's theses) - 30,
- received domestic and international awards and distinctions - 4.

As previously mentioned, the main area of my interests have always been, from the beginning of my research work, and still are designing and producing the new types of materials dedicated for electrical power engineering purposes and the design of various types of structural solutions related to the topics above. During the entire period of my scientific work, these studies were carried out in a way to enable application and commercialization of the obtained results in production plants both in Poland and for selected examples also beyond the borders of our country. The direct results of this work were my master's thesis and doctoral dissertation which I have written, implemented and defended. Also another example of direct results is my habilitation monograph published in 2018, which according to my assessment meets all the criteria for the main scientific achievement in the procedure of granting the title of habilitation degree.

One of the most important scientific and research issues, in which I took part after I obtained the Doctor of Technical Sciences degree, were works on designing a new type of material, geometry and processing technology of load and current carrying equipment used in tramway and railway overhead traction lines. These research were carried out in the years 2014-2017 in a consortium of AGH and KUCA Sp. z o.o. as part of an Innotech III project, which I had the honour to lead on behalf of the AGH. As part of this research, the existing structural solutions used in tramway overhead traction lines were firstly analysed, and then on the basis of the obtained research results, guidelines for designing a new generation of equipment were developed. Subsequently, research were conducted on the selection of the optimal type of material and optimal geometry of individual fittings and based on them an industrial concept of their production technology was developed. The load and current carrying equipment was finally made out of the new alloy i.e. CuZn37Ni1Si0,5 which were produced in a continuous casting line and next die forged and heat treated. Afterwards their exploitational properties were tested in laboratory and field conditions on the actual tramway line. On the basis of positively verified structural correctness and functional properties of equipment (all elements developed during the project from the moment of their assembly on the tramway line in Poznań are still in use in the normal operation of passenger tramway traffic) their final production technology was developed and next patented and commercialized. In the end all of conducted works allowed to implement designed equipment in the permanent industrial offer of a consortium leader and are now offered as solutions dedicated for tramway lines with the simultaneous possibility to use them as alternatives to the currently used elements in railway overhead traction lines.

Another example of research and development works carried out under my leadership within the scope of railway overhead traction field was research aiming to develop a complex measurement system of contact wire wear, its suspension height and stagger. Above mentioned works were carried out between 2015 and 2018, in a consortium consisting of AGH and the company KUCA Sp. z o.o. as part of the PBS3 project. During the research works detailed requirements and guidelines for designing a new type of measuring device were created allowing to develop the final concept version of the system consisting of a specially adapted scissor pantograph frame, a measuring strip mounted on the pantograph instead of contact strips and auxiliary equipment like power supply and wireless data transmission to the recording equipment. The measuring strip itself, as the most important element of the discussed system, was made of polyacetal and took into account the use of proximity detectors allowing to record the contact wire wear and and its stagger. Height measurement is carried out by device through a small-circle rotation encoder attached to the base of the measuring pantograph on the main power transmission shaft of the current collector. All data registered using the above mentioned sensors are then processed by the set of multiplexers, from where they go to the analysing processor and are next sent wirelessly to the recording computer along with the GPS position against which the measurements were made. After completion of the project (June 2018), the testing device will be subjected to the implementation procedure for production and sale and will be offered by KUCA company as the only measurement system of this type allowing to determine the correctness of the overhead traction structural parameters.

As it was already mentioned, the main area of my interest during the last years of my scientific and professional career were research on new types of materials and processes of their production as well as new types of construction solutions dedicated to railway and tramway overhead traction lines. Regardless this does not mean that only such R & D works were carried out by me during my work at the Faculty of Non-Ferrous Metals at AGH. During the last years I have also had the pleasure, at the request of the project manager from AGH - Professor Tadeusz Knych, to be responsible for conducting works and carrying out research on the development of new type of material called "UltraWire" which is a nanocomposite of copper-carbon nanotubes with potential above standard electrical, mechanical, thermal properties and corrosion resistance. Another aim of the project was to develop a pilot industrial plant for the production of Cu-CNTs UltraWire for electrical purposes. This works was carried out between 2013 and 2016 as part of the FP7 project in a consortium of 14 scientific and industrial units, among which were the largest European manufacturers of copper products and semi-finished products, i.e. companies such as Aurubis, Wieland, KME or Nexans and University of Cambridge functioning as the project leader and at the same time supplier of carbon nanotubes. As part of the consortium the Faculty of Non-ferrous Metals at AGH, as a scientific unit specializing in the processing of copper and its alloys, was responsible for developing a method allowing to combine carbon nanotubes with copper using continuous casting method and independently so-called powder metallurgy process. All of the work carried out under the European project allowed to develop the Cu-CNTs composites with evenly distributed carbon nanotubes content up to 2 wt. %, which were characterized by an increased electrical conductivity of about 8% at 400°C, about 15% lower degree of relaxation of internal stresses and simultaneously about 20% higher Young's modulus comparing to pure copper.

Currently, my scientific activity is still focused on the practical application of my scientific research, which may be confirmed by the fact that since 2018 I became a leader (from the AGH side) of two projects co-financed by NCBiR (The National Centre for Research and Development). One of the above mentioned projects is focused on a recycling technology for manufacturing load and current carrying railway equipment based on copper alloys for overhead traction line systems (project: POIR 3.1.2 Innovative Recycling) and the other one is focusing on the development and implementation for production a specialized connection system REKIN-AL dedicated to aluminum enamelled wires (project: POIR 4.1.4 Application Projects) .

Regardless of leading the above indicated projects, I have also contributed in the role of main developer and developer in the realization of 13 projects on issues related to widely understood metallurgy and material engineering of non-ferrous metals. In addition, during this period I was also the head of work and main developer in the realization of 13 works commissioned by the industry. The most important from my point of view was related to the development of database of high-strength and high-conducting copper alloys, which was carried out in several stages, in 2012-2016 period and was commissioned by the European Copper Institute. As part of the preparation process for the creation of the database, more than 1000 publications from around the world have been analysed regarding the previously selected copper alloys which made it possible to determine the actual scope of their basic, mechanical, exploitational, technological properties, chemical composition and also their potential use in various non-ferrous metals applications. All collected and processed in the next step data was then used to design and develop an IT web tool, which enabled to perform an advanced search through all collected information's. One of the primary goals of the project was to help technologists working in production plants and looking for new material solutions with a strictly defined set of properties. Another equally significant role of the database was to work as teaching aid for students and lecturers looking for material data to carry out their own research. The developed database is still available free of charge at: http://conductivity-app.org/ and up to this day nearly 300 000 users from all around the world has benefited from its resources.

Within my scientific activities I have been in the past and I currently am a member of 13 consortia gathering partners such as: University of Cambridge (United Kingdom), Aalto University (Finland), Institute Of Occupational Medicine (United Kingdom), Outotec Oy (Finland), National Grid Electricity

Transmission Plc (United Kingdom), Aurubis (Belgium), Nexans SAS (France), KME Gmbh & Co KG (Germany), Peugeot Citroen Automobiles S.A. (France), Wieland Werke AG (Germany), Invro Ltd (United Kingdom), Thinkstep (Germany), Institute of Non-Ferrous Metals (Poland), KUCA Sp. z o.o. (Poland), ERKO Sp. z o.o. sp. k. (Polska), Carbo-Graf Sp. z o.o. (Poland), BOLMET S.A. (Poland), Energetyka Solarna Ensol Sp. z o.o. (Poland), Adamet Witold Gajdek, Adam Pęczar Sp. J. (Poland), Tele-Fonika Kable S.A. (Poland), Institute of Electronic Materials Technology (Poland), Polskie Sieci Elektroenergetyczne S.A. (Poland), MABO Sp. z o.o. (Poland), Institute of Metallurgy and Materials Science of the Polish Academy of Sciences (Poland). As part of these consortia, widely understood scientific cooperation was established, which enabled the realisation of not only specific granted projects, but in many cases it also led to the idea and elaboration of new projects that allowed and will allow to realise and complete basic and industrial research works in the nearest future. My participation in the above mentioned consortia was associated with the contribution in 8 different research programs presented and briefly described below:

- 7th framework programme – the seventh framework program of the European Union in the field of research and technological development – financed from EU funds,
- Applied Research Program – a support program for the science sector and the enterprise sector in the field of applied research from various fields of science and industrial sectors,
- INNOTECH – a support program for the science sector and the enterprise sector in the field of implementation of innovative projects in various fields of science and industry,
- Demonstrator+ – a program supporting research and development works on a demonstration scale,
- Techmatstrateg – a strategic program of scientific research and development work "Modern material technologies",
- Innovative Recycling – a program which goal is to increase the innovation of the domestic recycling sector of mineral resources and lumber in the perspective of the year 2026,
- Application Projects – POIR project focusing on conducting R&D works (industrial research and/or development works, which may be supplemented with pre-implementation work),
- Fast Path – industrial research and development works carried out by enterprises.

The results of my research, which are closely related to my scientific work and the research projects I mentioned above, have enabled me to receive (as a co-author) 12 national patents and 2 international ones, 15 national and international utility models, and to develop and send to the patent office for additional 9 applications for inventions and utility models (co-authorship). It is worth noting that in the vast majority of cases, the patented solutions have found practical applications in specific non-ferrous metals industries, being permanently implemented into the sales offer of the companies that have carried out the research and development works together with AGH. In addition, all the above mentioned works allowed me to develop, as a co-author, in total 44 publications in both domestic and international scientific journals and to present 9 papers at domestic and international conferences and scientific seminars.

My scientific activity is also related to reviewing as an expert, the realisation effects of projects which are co-financed by the National Center for Research and Development (NCBiR). All of above mentioned works were done under the contract to Idipsum Sp. z o.o., which authorized me in the years of 2015-2017 to review a total number of 11 R&D projects such as Demonstrator+, Innotech and Fast Path. Apart from that, I am also a certified scientific, technological, economic and business expert on behalf of the National Centre for Research and Development, authorized to evaluate projects both at the stage of their application and the effects of their subsequent realisation.

In addition to my scientific and research achievements after graduating the Doctor of Technical Sciences degree, I was and still am involved in **teaching activities** at the Faculty of Non-Ferrous Metals, which began officially on the day I was employed at assistant position on October 24th 2013. This type of activity in my case is first of all related to teaching students at branch of studies such as metallurgy and management and production engineering, in following specializations: metal forming, metallurgy and recycling of non-ferrous metals, production engineering and application of non-ferrous metals and materials and technologies in electro-energetic systems. I am also responsible for classes, as part of these fields of study and specializations, related to generally understood engineering design using modern numerical methods on the following subjects: CAD/CAM, engineering design, finite element method and designing of metal forming processes. I was also responsible for teaching classes related to the basics of non-ferrous metals manufacturing and processing, i.e. continuous casting processes (classes in English language), metal forming processes (classes both in Polish and English languages). In addition, I also had the opportunity to teach students about technological aspects related to the use of various types of metal processing in industry, i.e.: technologies and production techniques in cable manufacturing, devices and tools in cable manufacturing and technologies for the production of metal composites. From all of above mentioned classes, the majority were laboratory, design and seminar classes. Furthermore in the case of CAD / CAM, engineering design, finite element method and continuous casting classes I was responsible for preparing and conducting lectures.

One of the most important teaching achievement for me is the privilege to be a supervisor of diploma theses related to both engineering and master's studies. After graduating my doctor's degree, I have been the supervisor of 30 theses in total, of which 12 are engineering and 18 are master's theses. Additionally, as of today I am preparing students for scientific defence of 2 master's theses and 2 engineering theses, which should take place by the end of 2018. Apart from that I am also an assistant supervisor of two doctoral dissertations at the Faculty of Non-Ferrous Metals. First one concerns the field of design and the research on properties of multi-component Cu-Zn-Ni-Si brass intended for power purposes and the second one on the influence of continuous casting process parameters on the segregation of components in AlMgSi alloys.

What is in my opinion also extremely important is that my teaching achievements goes beyond activities related only to teaching in classes and being a supervisor of engineer and master theses. Direct effect of additional activities is i.e. reactivation on my initiative in 2016 (after a six years of break) the Student Research Circle which interests in metal forming processes under the new name of SRC "Wire", of which I am currently the scientific supervisor. Also in the same year a Doctorate Research Circle was created under the title of DRC "Deform" which is the second one in the scale of the entire university, gathering candidates for doctor's degree. The scientific scope of interest for both of the above mentioned organizations are closely related to each other in the field of metal forming process of non-ferrous metals and allows to integrate students and candidates for doctor's degree with academic staff from the Faculty of Non-Ferrous Metals. As of today, both organizations associate 17 students from third, fourth and fifth year and eight candidates for doctor's degree who represent all fields of study at the Faculty of Non-Ferrous Metals i.e. Materials Science, Metallurgy and also Management and Production Engineering. Worth emphasizing is the fact that from the very beginning both organizations actively participate in grants and student initiatives, which allowed in early 2017 to receive and conduct two original projects as part of the "Rector's Grant" initiative. The realisation effect of the first of them entitled „Design, build and development of overhead railway traction model with elements which were made by academic staff from the Faculty of Non-Ferrous Metals" is a modern exhibition that can be seen on the first floor in the main corridor of the A2 building. This exhibition is a valuable teaching aid in the education process of students by allowing them to identify methods of practical use of the elements obtained from non-ferrous metals and their alloys. Moreover exhibition presents the combination of various technologies allowing to obtain and design specific properties of final products and also allows to learn about their practical application. Furthermore it helps to understand the overhead railway construction and its principal operation. The second project carried out by students and candidates for doctor's degree under the "Rector's Grant" project concerned the construction of a test stand allowing to simulate the current heating of metal products in a protective atmosphere which are dedicated for conductive elements of transmission and railway electrical power systems. The stand which was developed and made as part of the project allows to test various types of load and current carrying elements by causing in them a thermal effect under electric current flow conditions with various current intensities over time. It is the first such laboratory test stand at the Faculty of Non-ferrous Metals, which will be used to teach students and to carry out research works research commissioned by the industry.

The last type of my activity while working as an assistant and assistant professor (since November 24th 2017) is **the organizational activities** conducted continuously at the Faculty of Non-Ferrous Metals. This activities include participation in two organizational committees, i.e. in the committee of scientific-technical seminar of the NOEL consortium "Modern Materials and Technologies for Electrical Power Engineering" which took place on September 26th 2014 in Krakow, where I was responsible for co-organization of thematic session, giving a plenary presentation and also, organizational assistance during the visit of meeting participants at the laboratories of Faculty of Non-Ferrous Metals. Furthermore I have also participated in the organization and preparation of materials for the thematic session on the international seminar entitled "Ultra Conductive Copper-Carbon Nanotube Wire - UltraWire Open Day", which took place on September 22nd 2016 in Cambridge, United Kingdom and were I also gave a plenary speech at.

My organizational activities at the Faculty of Non-Ferrous Metals at AGH are also related to the preparation and updating of the teaching program at the Syllabus AGH base, where I am responsible for the program of classes in the field of Metallurgy, both at the engineering undergraduate studies and masters graduate studies. In addition, in 2017, I was appointed by the Dean of the Faculty of Non-Ferrous Metals at AGH to the Faculty Teaching Audit Team, where I am a member responsible for the quality assessment of the teaching facilities at the Department of Metal Working and Physical Metallurgy of Non-Ferrous Metals. In the same year, the dean of the Faculty of Non-Ferrous Metals at AGH also appointed me as a member of the undergraduate examining board in the field of Metallurgy.

Finally, I would like to point out that since 2013 up to this day I am a member of the Polish branch of the Wire Association International organization which is the largest cold drawing related organization in the world and an expert of the European Copper Institute (since 2015) in the 4C platform (Copper & Conductivity Platform) were I was actively involved in the works aimed at develop and promote copper as an energy conductor. Additionally, I was also a lecturer for the European Copper Institute through the Leonardo ENERGY platform, where I had the pleasure to prepare, deliver and publish a presentation entitled "Copper and copper alloys in railway systems".

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