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15 YEARS JOURNAL "MECHANICS, TRANSPORT, COMMUNICATIONS" RESEARCH IN MATERIAL SCIENCE, PUBLISHED IN THE JOURNAL "MECHANICS, TRANSPORT, COMMUNICATIONS" – REVIEW. Part I

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Abstract: *This paper reviews the research in the field of material science. Scientific analyzes are made on modeling and optimization of technological processes, welding of materials, technological tasks for the development of materials and their technologies*

The first part of the analytical review is devoted to an approach developed by researchers at the „Todor Kableshkov“ University of Transport. This approach can help interdisciplinary teams of different higher schools to support the Bulgarian economy and science. Various technological tasks related to the repair of worn surfaces after application of coatings with reinforcing properties have been considered. The refinement of the different tasks and the corresponding decisions lead to the creation of an approach that helps to determine a rational solution in determining effective solutions, which is related to the reduction of energy costs or the raw material used.

The second part of the review analyzes material material studies of lecturers from University of Transport "Todor Kableshkov" and their colleagues.

A total of 101 papers are analyzed and commented in the review paper, divided respectively into 51 in the first part and 50 in the second part. An emphasis is placed on the contribution of the „Todor Kableshkov“ University of Transport in the development of Bulgarian material science.

The papers viewed and analyzed in this review cover research over a continuous period of twenty-five years.

The review takes into account the accumulated experience of the researchers at the „Todor Kableshkov“ University of Transport, through which it is possible to reach important decisions in the field of material science using universal algorithms.

The preparation of this review on research in this area is dictated by the idea of generalizing the results of theanalyzes carried out and giving in concentrated form information about the results obtained by the authors.

Part I - Contribution of the University of Transport to Bulgarian Material Science

During the 15 years of the development of the Academic Journal „Mechanics, Transport, Communications“, along with the development of individual sections, the field of material science was developed. A detailed description of the contribution of „Todor Kableshkov“ University of Transport in materials science was developed by the German academic edition of Lambert in 2014 [1], which quoted a number of ideas in the journal. The quoted approaches described in detail [2, 3, 4, 5, 6, 7, 8, 9] have their prehistory. In the mid-nineties of the last century, N. Tontchev won the first project of „Todor Kableshkov“ University of Transport (TH 566/95) at the Scientific Research Fund. Within the framework of these commitments, the direction of modeling and optimization of some technological processes, incl. and underwater welding and more. An algorithm [10] was created, a computer system, and our message was presented at the 4th World Engineering Conference held in Minnesota, USA in October 1995. Later in 1997, Int. Multiple Criteria Decision Making, FUCAM, Mons, Belgium, have been approached with various technological solutions [11]. Some of these early studies at „Todor Kableshkov“ University of Transport are noted here because they contain some useful ideas that have not lost their relevance.

Since the specialization of the higher school is related to the transport science, where the question of weight, strength of the material of the facility and its factual and environmental security are of utmost importance, some of the studies were aimed at weight reduction by increasing the strength of the material [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22]. The main underlying assertion of all these studies is that in modeling the properties of iron-based materials as a function of chemical composition, it is possible to identify effective solutions by defining a multi-criterion task for the complex of characteristics determined by the decision-maker. Arranging these effective solutions depending on their composition and/or their energy intensity leads to the identification of an innovative solution. Following this trend, weight reduction through strength is directly related to fuel consumption and carbon emissions.

The research has demonstrated the possibility to explore theoretically with the help of modern computer and software capabilities, the influence of the individual alloying elements on the values of the end properties, using the artificial neural network for approximation and the genetic algorithm for optimization [23,24,25]. The proposed methodology proposal and the specialized software developed to help determine the optimal composition is necessary for the future development of the system "composition -processes -properties -economy and rationality" in the creation of new materials. In the field of preforms, the modeling of the technological cost as a function of technological and organizational characteristics is nominated for different grades of steel by means of aggregated indicators allowing the assessment of equally feasible technological routes [26].The solution of such questions is related to the formalization of the two groups of parameters, the chemical composition (by means of alloying elements in number, quantity and types, whereby it is possible to obtain material strengthening) or by thermal treatment, which – by its parameters – also to perform strengthening. Through these two sets of parameters defining the two branches of the material task of material science, the desired level of hardening of the material is achieved. This formalization is common to the material science and the contribution of the „Todor Kableshkov“ University of Transport consists in creating algorithms, numerical methods and software to solve this class of problems. Initially the task was solved only in terms of the parameters of the technological process [10]. Processes of mating, plasma layering, homogenizing thermal treatment of cast aluminum alloys, ionization of the class of tool steels for heat treatment have been optimized.

The refinement of solutions has led to the creation of an approach that enables a rational decision to be made when determining effective solutions, which is related to the reduction of energy costs or the raw material used. Such a study is [27]. It specifies a representative of a particular class with the corresponding consumer requirements for the mechanical properties after the chemo-thermal treatment. By this is defined, implemented and implemented, a methodology for studying a certain complex of properties in the study of a class of tasks in the field of material science. The automated application of the approach has led to the creation of specialized software.

The methodology is able to choose material of a certain class of steel, providing the necessary complex of properties with control of the energy costs. These decisions are assessed with the achieved benefits in the concerned area. The proposal [2] to the decision-maker (DM) does not work in the criteria plane, but in the variables' plane, as well as the use of different /up to five-six/ color restriction intervals, turns out to be quite unconventional. However, these two prerequisites are capable of performing a very useful analysis of different processes at this stage with up to four variables. The ability to improve properties of a representative grade grade steel has been demonstrated through a multi-criteria procedure for determining the amount of adding alloy elements using a small database [28].

The new application of the development of this technology branch is conceived by the capabilities of today's applied CAD / CAE packages. With their help, under certain initial and boundary conditions, it is possible to simulate a technological process in the field of casting, plastic deformation, and from CAE calculations to determine levels of different types of defects that, using the approach, may be removed. In addition to defects, the software developed can also be used to determine rational parameters ranging from a variety of technology parameters. Simulation tests and optimization of the technological costs were carried out using computer models to elucidate the influence of technological and organizational parameters on the basis of the expert knowledge of the metalworking preparations [29, 30, 31].

A large number of the cited studies are associated with the first branch of the straight-forward task of material science that treats the chemical composition and its synergistic effect on properties. They are inherently a theoretical-experimental study with established approaches for determining effective solutions for the composition and quantity of alloying elements, as selected factors determining the operative regimes in the processing of alloys on an iron base improve the quality by predetermined control parameters.

In a number of studies, the two approximation techniques are used to create the models that will subsequently be optimized. The main approximation cases are related to regression approximation and approximation of artificial neural networks. After the approximations made in the studies, Pareto's optimization compromise is solved because all the problems of the material science are connected with a complex of properties.

These properties are contradictory and their value depends on the two sets of parameters (the chemical composition and the parameters of the thermal treatment). These values of mechanical properties determine the wide range of applications of the studied materials. Analyzing this range satisfies desired consumer needs. For the implementation of the approach, data that can be obtained either by experiment or by simulation studies are needed. These data give the relationship between the studied two branch parameters on the one hand and the studied properties on the other. The solution of the task passes through two main stages: modeling by approximation of raw data, second, multi-criteria optimization. A team at „Todor Kableshkov" University of Transport has made a significant contribution to building a system that supports the optimization solution by creating a friendly software that analyzes multi-factor quality indicators (chemical indicators), secondly, defines effective solutions related to the identified innovation. The optimal conditions for workability by chipping, as

well as the influence of the alloying elements and the mechanical characteristics on this technological index [32], were determined by the study.

This approach was appraised by a wide audience of students and teachers from all over the country as an opportunity for „Todor Kableshkov“ University of Transport to cooperate with interdisciplinary teams of different higher schools in support of the Bulgarian economy and science. It should be noted that one of the proposed approaches is able to significantly reduce a priori information to generate an optimal composition or to determine rational parameters of the technology. This helps designing compilations to fill databases, reduce the amount of experiment in metallurgy, which is expensive and the information is difficult to reproduce.

Multi-parametric analysis is valuable, but at this stage it is limited in terms of the discretization performed on the various input parameters. Another possibility of analyzing quality indicators is a method unified by us on the ideas of Taguchi's method. In [33, 34], regression analysis was applied for the purpose of iron, titanium and magnesium alloy quality management. This study offers an original method for multi-criteria optimization of alloying properties of the aforementioned alloys. To the technological tasks can be added the tasks related to the repair of worn surfaces after application of coatings with enhancing properties. This idea is devoted to [35, 36, 37, 38, 39, 40, 41, 42, 43]. The properties of these coatings have been tested through specialized tribological tests [44,45,46,47]. The tribological tests of „Todor Kableshkov“ University of Transport have contributed to the creation of an impact-abrasive wear [48] bench with which experiments were carried out. The experiments were performed by arc welding and welding with tubular electrode in a protective gas environment.

All the above-mentioned tests are presented in the training process of the authors of the research and in this connection the following methodological studies have been formed[49.50].In addition to the approximations with neural networks in alloy testing, classification is also useful. Such research relates to [51].

Conclusion

This review covers goal-formulated research in the course of 25 years. During this period, experience has been gained with the help of which solutions from an area beyond the above can be reached. Algorithms are universal. They can be applied in the areas of technological systems and processes management, which makes the proposed approach and methodology extremely universal. The team of University of Transport „Todor Kableshkov“ distributed this approach with the intention to propose the definition, solution and implementation of applied tasks in the field of Bulgarian economy and science.

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