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On the state of materials science and engineering in Romania's educations

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Abstract. The present work synthetically presents the role of the materials engineer in research and production activities, the main professional skills, the situation of the field and specializations in the national nomenclature, as well as the precarious state of the downward evolution of the number of students, respectively of the attractiveness of materials engineering. Some proposals are made to increase the visibility of the field and specializations of materials science and engineering both from a didactic perspective and the importance for industrial production activities and product performance.

Keywords: materials science and engineering, professional skills, materials engineer.

1. The role of materials science and engineering

The design and construction of high-performance and reliable machines, equipment and devices requires, first, the use of high-performance materials. These materials, as well as their elaboration and processing technologies are created, designed and used in an optimal way by a specialist called "materials engineer", a new profession in Romanian higher education and industry, inspired by the technical education systems of developed western countries.

The dependence relationships of the functionality and performance of the products on the material and applied technologies are shown in the adjacent figure [1,2]. In all times, new materials have been developed and old ones have been perfected. Their production and use have traveled a path that started with stone, passed over bronze to iron, so that today it continues with the most sophisticated metallic, plastic, ceramic or composite materials, their development being the condition for

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the advancement of the mankind [3, 4]. Materials science and engineering, worldwide, are allocated among the largest research funds, thus training an impressive number of engineers and researchers and ensuring the highest rate of return on invested sums.

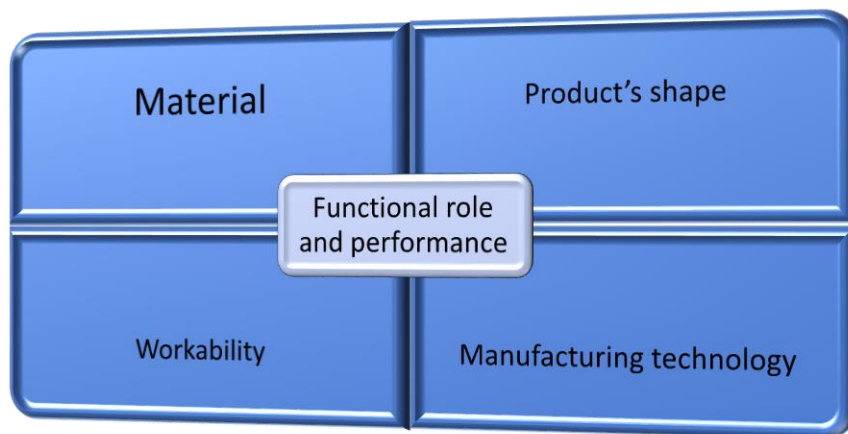


Fig. 1. The interdependence between the factors that influence the functional role / performance a product [1,2].

In fact, the Research Programs for Technological Development and Innovation of the European Union include studies and research in the field of materials among the priority funding areas at each edition.

Years ago, the political decision-makers in Japan established that three areas are priorities for the future development of the country: Information engineering (storage, processing and transfer of information), biotechnologies, respectively technologies for obtaining new and advanced materials for all industries. As a result of this decision, the most significant human resources from research - development, innovation and financial resources were directed to these fields [5]. In the U.S. and Europe, this was achieved much later, which explains the gap between their development and that of Japan, especially in the field of new materials.

There are no doubts so far, both in the past and in the present, regarding the importance of expert knowledge in materials, being known that today as a thousand years ago, those who mastered the materials also dominated the world. In the past, this led to the superiority of weapons, and today it leads to performance in equipment, apparatus, ensuring the comfort of life and health, of high-performance products applied in information technology and communications.

2. Skills and occupations

The specialist in materials science and engineering is thus directly involved in the production, processing and rational use of high-performance metal, ceramic, plastic or composite materials, materials with precise functions for cutting-edge techniques in machine building, nuclear technology, aviation technology, electronics and electrotechnics, information and communication technology.

The engineer in materials science and engineering must thus become a specialist equipped with a wide field of interdisciplinary knowledge, capable of performing in any sector of engineering activity, competent in the selection, design, development and processing of materials, being accessible in the most complex research laboratories or industrial units. The activities of consulting, expertise and analyzes in the field of particularly requested materials are well paid and create the premises for the specialist in materials to organize private offices.

Any small, medium or large company producing parts, sub-assemblies, devices, machines or machines needs specialists in materials science and engineering. Any producer and trader also needs such specialists. The competitive market economy implies competition, quality, diversification, costs as low as possible, in a word progress, and this requires more and more specialists in the science and engineering of materials, to work in the design activity, in control laboratories, research and consultancy.

In designing and making a product, the issue of materials must necessarily be correlated with the processes of elaboration, processing, processing and exploitation. That is why a good engineer must have complex training. Materials science and engineering must be able to produce materials whose properties determine the performance and reliability of the product. The wide range of properties and diversity of materials has led to an interdisciplinary approach between engineering and materials science.

Good designers are those specialists who have extensive knowledge in the field of materials science and engineering. It must be said that among the many problems that an engineer will have to solve in engineering activities are those related to design mistakes due to the incorrect choice of materials.

Thus, the main professional skills that must be acquired by future specialist engineers in the field of materials can be briefly mentioned:

Selection, design, development and characterization of materials.

- Choosing the optimal technological options for elaboration and processing in accordance with the conditions of productivity, cost, environmental protection (clean technologies).
- Designing technological processes for processing various categories of materials for industrial use: metallic, polymeric, ceramic, composite.
- Design, operation and maintenance of machines and technological equipment for material processing.
- Management and control of the technological processes of elaboration and manufacture of various categories of materials for industrial use.

- Preparation of feasibility studies and expertise in the field of materials and their processing.

Currently, alongside studies and research on the industrial development of new and advanced materials of all classes (metallic, ceramic, polymeric, composites, nanomaterials, more recently, metamaterials), materials science and engineering must respond to a new challenge, that of ecomaterials and of ecotechnologies.

Eco-materials are by no means a new type of material. The term eco-material is used to highlight the fact that from the moment a product is designed, environmental issues must be considered and for the stages of elaboration, processing, exploitation and recycling.

Therefore, eco-materials are materials that are harmless to the environment or with an active role in preventing pollution (for example, catalysts for the treatment of combustion gases), or in reducing pollution already present (depollution materials), functional eco-materials.

The development of ecomaterials must be seen as an overall issue related to the entire ecosphere involving:

- the development of materials in which the physical, chemical, mechanical, thermal and/or functional properties are improved and implemented, so that they support humans.
- harmonious coexistence with the ecosphere by minimizing the negative effects produced on the natural environment.
- optimization of existing technologies and/or application of other "clean technologies" to ensure healthy living conditions in harmony with nature. The materials must be "friendly" not only with the environment but also with people.

In the list of occupations with higher education in the COR Classification, there is a relatively small number of occupations for the field of materials engineering [6].

The occupations in the list are those specific to the industrial and research activities of steel and metallurgy, without qualifications specific to the other types of materials and technologies of elaboration and processing, such as polymeric, ceramic, composite, functional materials, etc.

3. Structure of the "Materials Engineering" field of study

According to the Nomenclature of fields and specializations/university study programs, the following study programs/specializations are included in the "Materials Engineering" bachelor's study field (DL207010170) (Government Decision no. 412 / 2024 regarding the approval of the Nomenclature of fields and specializations/ university study programs and the structure of higher education institutions for the academic year 2024-2025) [7]:

- Materials science
- The engineering of the elaboration of metallic materials
- Materials processing engineering
- Applied informatics in materials engineering

- Biomaterials engineering
- Engineering of metallic materials.

The study programs are differentiated by their curricular content. They are defined by the mission and correspondingly by the competences expected to be acquired by the graduates, according to the educational plans and subject sheets.

The education plans contain the following types of fundamental subjects (as a rule, common to several engineering fields), domain, specialty and complementary. Field disciplines are the disciplines common to all university study programs in the same undergraduate field.

The specialized disciplines are the defining ones for the specialization provided by each of the bachelor's degree programs in the same field of study. The nomenclature of these subjects, corresponding to each study program in the bachelor's field, are indicated in the ARACIS Standards without the obligation to include all the subjects in the nomenclature in the curriculum of a certain study program. The sequence of specialized subjects in the education plan must be adequate and coherent, so that the acquisition of the specific skills of the respective specialization is ensured. It is recommended to schedule them in the curriculum according to the field subjects no earlier than the 5th semester. The list of specialized subjects can be completed at the request of the universities. Determining the type of specialty subject depending on the optionality of the subject remains at the discretion of the university [8].

Initially, at the meetings of the representatives of the universities, it was agreed as the name of the field, "Materials Science and Engineering", a name established in the European education systems. Later, when establishing the content of the nomenclature of fields and engineering specializations, with the intervention of some influential representatives, it was decided that the phrase "Materials science" should be attributed only to the name of the fields of study of materials specific to chemical engineering.

Also, the representatives of the universities that had a profile of materials agreed that in addition to the study of metallic materials established through the existing specializations of steel, metallurgy and technological equipment for hot processing, studies of polymeric, ceramic, composite materials should be introduced in the curricula of the new specializations, semiconductors, nanomaterials, of materials with special properties and applications, both in terms of their definition, design, characterization, and processing (technologies and specific technological equipment).

4. The State of Materials Science and Engineering in higher education in Romania

The "Materials Science" bachelor program/specialization has been accredited and operates at UNST Politehnica of Bucharest, Technical University of Cluj-Napoca, Politehnica University Timișoara, "Gheorghe Asachi" Technical University of Iasi,

"Transilvania" University of Braşov, "Dunărea de Jos" University of Galaţi, "Valahia" University of Târgovişte.

The bachelor program/specialization "Metallic Materials Elaboration Engineering" (former siderurgy specialization) was accredited and operates at UNST Politehnica Bucharest and " Dunărea de Jos" University of Galaţi, "Valahia" University of Târgovişte.

The bachelor program/specialization "Materials processing engineering" (former metallurgy program) was accredited and operates at the UNST Politehnica of Bucharest, the Technical University of Cluj-Napoca, the "Gheorghe Asachi" Technical University of Iasi, the "Transilvania" University of Braşov, " Dunărea de Jos" University of Galaţi.

The bachelor program/specialization "Metallic Materials Engineering" (a return in the form of a mix to the former steel and metallurgy specializations) was provisionally authorized and operates at the UNST Politehnica of Bucharest, following the tradition, human potential and scientific concerns of the teaching staff.

As we have shown in the works [9,10], the bachelor's programs are intended to provide general specialist training, and the master's study programs are the ones that ensure the deepening of knowledge and the development of skills in a certain direction. In these coordinates we consider that certain programs in the field of materials engineering do not meet these requirements

The "Applied Informatics in Materials Engineering" bachelor program/specialization was accredited and operates at UNST Politehnica of Bucharest, "Transilvania" University of Braşov, "Dunărea de Jos" University of Galaţi. We believe that both the content and the name of the program are inappropriate for an undergraduate degree program. It could be accepted as a master's program at most. To be able to study the informatics in materials engineering, you must know materials engineering. It was introduced with the aim of making the program 'commercially' attractive, which is hardly acceptable in the academic environment of education. Moreover, with all the attractiveness of the name, the lack of interest shown by the candidates for admission led in some universities to stop the operation of the program.

The "Biomaterials Engineering" bachelor program/specialization was accredited and operates at "Transilvania" University of Braşov, "Valahia" University of Târgovişte. We believe that both the content and the name of the program are inappropriate for an bachelor level program. Biomaterials are a group of materials derived from the category of materials with special properties and therefore with specific applications. Therefore, the program could be accepted as an interesting master's program like the one at UNSTP Bucharest. As in the case of the previous program, it was introduced with the aim of making the program 'commercially' attractive, which is hardly acceptable in the academic environment. Education in general, respectively engineering training cannot be considered as the lack of interest shown in admission by the candidates, led in some universities to stop the operation of the program. And this program had the fate of the previous one.

Unfortunately, Materials Science and Engineering has not yet found its well-deserved place in Romanian society. Everyone recognizes and accepts the importance of materials in all sectors of industry, therefore also in areas close to us, such as health and quality of life. However, materials science and engineering is not viewed as a distinct field or specialization, its importance being neglected. It is easy to verify this. Ask your relatives or even more strangely, managers or specialists from the industrial environment, if they know what material science and engineering is and you will find that you will receive strange answers, from "I don't know" to "it is somehow a field of engineering that calculates the structures?". Ask the same people about composites or polymers and you will be even more surprised by the answer. The public, and unfortunately even industrial managers, are not properly informed about engineering and material science. They are familiar with the classical sciences - physics, chemistry, biology, geography, mathematics and modern technologies - computers, aeronautics, communications, automation, machine construction, mechatronics, etc. Today, however, their lives and professional performances depend more on materials science than on other disciplines.

In recent years, the reduction in the number of candidates for admission, respectively in the attractiveness of specializations in the field of Materials Engineering, both at the bachelor's and at the master's and doctorate levels, in all the universities that have accredited this field, has become more and more significant. It is found that many graduates and relatives confuse the field of materials with steel and metallurgy, industrial activities in decline because of the so-called ineffective privatizations, followed by the disappearance of most of the former profile combines.

If this downward trend continues, the danger of the abolition of the field and specializations of materials science and engineering is imminent in most universities, also due to financial inefficiency. Thus, teaching staff with high professional-scientific competence would be lost, as well as research and industrial activities that will be devoid of specialists in the field of material science and material production in the future.

5. What is to be done?

The field of materials science and engineering must find its own identity both within the nomenclature of fields and specializations in higher technical education, and in the consciousness of public opinion, as a separate field from mechanical engineering, industrial engineering or even metallurgical engineering. The new university curricula (curriculums, analytical programs, subject modules) that are being designed must meet at least two objectives: the first, to ensure the acquisition of flexible professional skills and the second to increase the attractiveness of the field, respectively the confidence of future admission candidates in the employment potential after completing the studies, with possibilities of further professional improvement through master's and doctoral schools [11].

The engineer - specialist in materials - should become a profession with a high degree of mobility and flexibility, with safe possibilities of change and easy adaptation in various professional conditions, depending on the demands of the labor market. There should be no unemployed material engineers.

Members of the scientific community, teaching staff in the field of materials science and engineering must make sustained efforts in order to obtain the correct, natural and deserved position of this field within the nomenclature of specializations in higher technical education, as well as its place in the industrial production environment.

It is necessary to make the economic environment aware of the role and necessity of engineers specializing in materials engineering for research, design and industrial production activities. It is also necessary to inform and make high school students aware, through appropriate and attractive methods, of the importance of such specialists as well as of the deep innovative and civilizing character of the field of materials for the industrial development of increasingly high performing products and goods.

At the same time, the specialized faculties aim to train specialist engineers with extensive knowledge of all classes of new and advanced materials that underlie progress and the comfort of life.

- A proposal to establish an undergraduate study program with a complex and well-defined content is: "Sustainable development in materials engineering", based on the following arguments and opportunities:

- The sustainable development of society requires, among other things, the provision of natural resources in time as well as the reduction of the negative impact on the environment of industrial activities.

- The technological processes in materials engineering, respectively the elaboration of materials, the processing of materials, the recycling of waste, constitute important risk factors for the degradation of the environment.

- The application of ecological technologies in the processes of development and processing of materials is an important factor in ensuring the protection of the environment, the rational use of natural resources, the application of the circular economy, the use of renewable energy sources, the use of ecological materials, the reduction of energy consumption materials and energy.

- The new proposed undergraduate study program has as its main objective the training of engineers with professional skills for ecological design activities, the knowledge and use of ecological materials, the design of ecological technologies for the elaboration of materials, the design of ecological technologies for processing materials, the design of ecological technologies for recycling of materials and waste, circular economy, ecological management.

- Practically, the content of the proposed program, "Sustainable development in materials engineering", is like the two existing undergraduate programs in the field of studies, "Materials engineering" (Materials processing engineering and Metal materials elaboration engineering), but with subject names

and content that ensures the sustainable development of society, current requirements imposed by the norms and standards of the European Union.

In the perspective of the political decision to "re-industrialize" the country, it would be the moment to reconsider the importance and necessity of the materials industries by promoting investments in the production of new and advanced materials in addition to those of the elaboration and processing of materials specific to the metallurgical field. They can be exemplified in this way, the production of polymer materials, ceramics, composites, ecological materials, functional materials with special properties that require new industrial technologies for innovative elaboration and processing, as well as priorities in the financing of research in the field of new and advanced materials.

All these programs should lead to increasing the interest, attraction and visibility of the field of "Materials Engineering" for admission to engineering education.

6. Conclusions

The ever-increasing demands of people for industrial products and goods that ensure increased comfort (for example: televisions, computers, mobile phones, construction materials, materials for the transport industry and automobiles, etc.) require an increase in their performance. Obtaining such products requires the use of materials with high specific properties.

The design, development and processing of new and advanced materials leads to the development of new concerns in research, to the design of new clean processing and manufacturing technologies, to the development of new industrial units, to the creation of new jobs, as well as to "civilization" the industrial production of new products and ecological goods for the environment, when implementing the circular economy.

Instead of an afterword:

- *The functional performances of the products are determined to the greatest extent by the MATERIAL and by the elaboration and processing technologies - attributes of the MATERIALS ENGINEER.*
- *There should be no engineer specializing in materials, unemployed.*
- *Today as a thousand years ago, those who mastered the materials also dominated the world.*

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