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THE IMPORTANCE OF TEACHING MATERIALS SCIENCE & TECHNOLOGY IN THE COURSE OF MECHANICAL ENGINEERING

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Abstract. *Mechanical Engineering has a more strait connection with materials than other engineering branch, through multiple aspects from processing to characterisation and utilisation. The study of this area of knowledge should be the fundamental aspect in the course. An analysis of the theme is done, suggesting the correct arrangement of the corresponding disciplines in the teaching of Materials in relation with the ones that should preceded and follow, as well as the contents, orientations and methods that could be used to reform some curricula and the consequent improvement of the Mechanical Engineering course and others branches related to.*

Keywords: *Mechanical Engineering, Materials, Teaching*

1. THE MATERIALS AND THE MECHANICAL ENGINEERING

The production, transformation and utilisation of materials have traversed a long way close to the history of Mankind, since silex till today. The imperatives of a modern technological system influence the development of a large number of classes and types of materials, having moreover different properties and performances, according to an enormous multiplicity of requirements in so different areas of engineering as astronautic, electronic, automobile industry and even in the fields of medicine or sports equipments.

All the great technological advances are related to the development of certain kind of material. In the structural materials area, the aerospace industry and the automobile industry have stimulated research, development and production of new materials, however once produced, they find applications in other fields, steep increase the spiral that links the materials engineering to other engineering branches "consumers" of these materials.

Nevertheless, the use of materials in a great scale brings necessary among technological problems, others like economical, ecological and even strategic, of an increasing importance, with political and social consequences, which can not be ignored neither by producers nor by users[1].

The knowledge that mankind have about materials began with empirism in which stay for thousands of years. The scientific interpretation of phenomenons is very recent, thanks to the joining of chemical analysis, mechanical testing and microstructure analysis. The Chemistry as a science began with Lavoisier by the end of the XVIII century and the metallography with Sorby by the middle of the XIX century. The arrival of mechanical testing began very early, with Hooke in the XVII century, not to mention Galileu or Da Vinci long before. So we can not ignore the first participation of Mechanics in the quantifying of the behaviour of materials and the strait connection since then with these two branches of knowledge sustain.

On the other hand, since the 50's the study of metallurgy has lost its encyclopedic character in favour of a more phenomenologic approach. It was possible to verify that the characteristics and the basic phenomenons are common in all the classes of materials, so does not justify the separation of the metals'study, already autonomous in Metallurgy, from polymers and ceramics, still integrated in Chemistry.

From this unified approach of the materials structure study and its implications in their own properties results the *Science and Engineering of Materials* which includes the creation and application of knowledgement relating the composition and processing of materials with their microstructure, and this one with the properties and their consequent applications. Therefore, it is essentially a comprehensive area acting as a link between basical sciences and research, and technological application of materials, which means all the engineering branches, namely the Mechanical Engineering.

Facing the actual state of knowledge, the strait connection between Mechanical Engineering and Science and Engineering of Materials can be presented by the binomial *structure-property* concept, which allow to foreseen the performance of materials from knowledge of the microstructure and the consequent use of this relation in reverse, promoting the correct microstructure in order to obtain the desired properties and performance, obtaining the highest point of this development with the "*tailorism*"[2].

The long and complex life cycle of materials (manufacturing, processing, characterisation, utilisation and recycling) represents nowadays a great part of the industrial activity, where, without doubt, the Mechanical Engineering is very important. In fact, all the engineering branches work with materials; however, we have to recognise that Mechanical Engineering (and also Aerospacial Engineering, Automobile Engineering, etc.) by the scope of the phenomenons studied and achievements to preside, and also by the volume and diversity of materials that consumes is far more related to Science and Engineering of Materials than any other. We must stand out the principal areas of interface among these two engineering branches:

- In the processing, the areas of mechanical technology of plastic deformation, machining, welding, casting, processing of ceramics and polymers, powder technology, mechanical and thermomechanical treatments, superplasticity and controlled forming, etc.
- In the characterisation, the mechanical and technological testing, the microstructural analysis.
- In the project of strucutres and mechanical equipments, selection of materials, problems with strength of materials as well as ruin (fracture, fatigue, creep and wear), failure analysis, life prevision.

2. THE CONTRIBUTION OF MECHANICAL ENGINEERING IN RESEARCH, DEVELOPMENT AND PRODUCTION OF MATERIALS

The strait connection between Mechanical Engineering and materials, which must be progressively distinguished in the course, reaching a great number of activities in which the mechanical engineer will work.

Besides the industrial aspects, above mentioned, we may consider others, even more connected to research and development, like possible incursions in reverse sense, or rather the contribution of Mechanical Engineering in material research, development and production, for having obviously a great diversity of mechanical problems.

Then, belongs to Mechanical Engineering a constant participation in the materials evolution, with the purpose of:

- To optimise the improvement of potentialities of existing materials, using an racional and criterious application, not only in technological but also economics and ecological aspects.
- To promote the development of new materials and the improvement of the existing ones to satisfy the increasing demand imposed by the industry, meaning an increase of mechanical and thermal resistance and reduction of weight and costs.
- To make a deep study about principal mechanisms of materials degradation (namely of mechanical nature, like fatigue, fracture, creep, wear, etc.) in order to increase the lifetime of goods and equipments and the safety of users.
- To create equipments, methods and standards more and more precise on characterisation testing of materials, evaluation of their properties and quality control.
- To promote the creation of standards on terminology and related aspects, useful to a correct selection, trade and use of materials.
- To create and actualise the materials database, well organised with easier access, making possible a great rationalisation and selection of materials.

3. THE MECHANICAL ENGINEER TRAINING IN THE MATERIALS AREA

The Mechanical Engineering course make the possibility to the future engineer to work in so many activities such as conception and design, production, management, inspection and control, research, etc. In this way the teaching have to keep the required level for the performance of these functions, giving the necessary ability of analysis and synthesis which allows in a correct way the resolution of the complex problems that engineers will face.

The Mechanical Engineering should be considered as a whole, indispensable to the above mentioned training problem, and not considering it as a sum of knowledge areas or separated subjects which may confer a certain final credit of participation.

The teaching of these matters which forms the curriculum of the Mechanical Engineering course should be made according to a basic and logic sequence, so that the disciplines attendance respects the precedence between those that have the basic concepts for the learning of others. The non appropriate sequence of several disciplines expressed in the curriculum plan (as verified in many cases) or as a result of extinction of precedence regimen, may obviously cause more and more problems to the students, against to what some of them believes, trying to pass difficulties as a result of certain reprovals.

Taking into account the considerations above mentioned about the link between Mechanical Engineering and Materials, the teaching of this matter should put on a special interest. Therefore, according to a general curricula analysis this relation between Mechanical Engineering and Materials is recognised in some Universities, however there are some where still not give a special attention to this connection[3].

The recent report of the Council Evaluation of the Portuguese Universities recommend the establishment of a discipline, named History of Science and Engineering, in the area of the Social and Human Sciences in Mechanical Engineering course, and in others related to, with the aim of getting new engineers with a technical and cultural academic training[4]. Through the strait connection that exists since the early time between History of Humanity, History of Technology and the Materials, this discipline should naturally include a first approach about the materials evolution and their technological, economical, environmental and social effects, providing to the students of Mechanical Engineering an initial interest for material, and take note about their importance.

The actual teaching of materials should be made at least at three levels, which corresponds to the same number of disciplines of a deep training character:

- At a first level, named **Introduction to Science and Engineering of Materials**, should teach the basic concepts, like the atomic structure of the matter, chemical bonding, crystalline structure, imperfections, strengthening mechanisms, phase diagrams, class of materials and their main characteristics, etc. The correct place of that discipline in the curriculum will depend on the previous attainment of basic notions of Physic and Chemistry, namely in the area of Thermodynamics, so does not seams practicable in the first year like happen is most Faculties.
- At a second level, that could be named **Structural Materials**, or **Materials of Mechanical Construction** should be taught in one level after the previous one, in which will study the proper materials for applications in mechanical engineering, always referring the sequence *processing-structure-properties-performance*[5], giving for each material the importance of technological, economical and environmental aspects which should preside to their application. The emergence of "new materials" and the "*tailorism*" in this conception and production should be important themes. The correct place of this discipline should depend on one hand, to the previous one, which is upstream to this discipline, and the other hand to those that should be downstream: the different disciplines which comprehend the designation of Mechanical Technology (plastic forming, welding, machining, casting, etc.) the disciplines of Mechanical Design, and also the ones that studies Fracture, Fatigue and Creep.
- Finally, the main discipline of Materials study, that could be named **Materials Selection**, the one that, having the previous knowlegdes about materials and their processing (in Technologies), about Design needs and about failure mechanisms (in Fracture, Fatigue and Creep), will became an important support for final discipline of the course: like Mechanic Design (in which the students prove their synthesis ability about the whole knowledge obtained all over the course). That discipline should include, among others, the following topics: Selection Criteria, Value Analysis, Cost/Benefit Analysis, Weighting Factors, Materials Selections Charts.

The two first disciplines of Materials must have an important experimental component, comprehending some mechanical testing, heat treatments, materialography (including the preparation of samples, microscopic observation, and microstructural analysis). The practical classes should have an obliged character, and presenting to students the technological and industrial aspects of theoretical concepts. So, for instance, in the study of heat treatments, will be teaching theoretical knowledges about the mechanisms of metallurgical transformation (*the know why*) but also the practical concepts about technical and industrial procedures, equipments, safety notions, etc. (*the know-how*), balancing the practical and the theoretical component of the course. This component should have a audio-visual priority. Finally, should organise study visits to factories, laboratories and centres of research related to production and applications of materials, making part of the whole course and allow an integrate view of it.

In the Selection of Materials discipline, the student must be familiarised with the consult of standards and specifications, as well as catalogues of metallic alloys and other materials and the instructions given by the manufactures about conditions of processing and service of these materials. The economic aspects, related to materials acquisition, processing and maintenance costs, should be always present.

The chapter dedicated to therminology and standardisation, should deserve, all over the course, a particular attention in the training of the new engineer. The standardisation of terms, symbols and notations is fundamental. Concerning terms, their missing may cause an

excessive use of foreign language, or an utilisation based on a literal translation, or intuitive concepts and common language [6]. But is not enough create standards and specifications, is necessary to became an effective use. As far as the symbols and notations are concerned, their uniformity will bring advantages for written and reading of technical and scientific literature.

CONCLUSIONS

- The great technological progresses, namely in the field of Mechanical Engineering have been very important for the concurrent progress of Materials, in which the research and development represents the main support of the actual technological system.
- To Mechanical Engineering belongs, by one hand, a permanent participation in the materials evolution, optimising the potential of the existing ones, stimulates the development of new materials, having a deep knowledge of failure mechanisms, improving the equipments, methods and standards of mechanical testing, etc.
- A solid knowledge of Materials is by consequence fundamental to Mechanical Engineering, so its teaching should be considered an important base in this course, as well as in similar ones
- That knowledge should be based in the present concept of integrated study of materials, in the relations *processing-structure-properties-performance*, standing out the development of new materials and the emergence of the "*tailorim*" in concept and production of these materials
- The teaching of Materials should be ministered at three levels or stages, coordinated with other disciplines upstream and downstream to it, being the last level the Selection of Materials in straight connection with the discipline of Design.
- A strong laboratorial component, comprehended basic mechanical testings, microstructural observation and heat treatments should make part of the Materials discipline programs, as well as the organisation of study visits to factories, laboratories and research centres focoused on the production or application of materials.

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