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Consolidation of Knowledge of the Subject "Calculation, Design and Testing Of Machines" Through Final Degree Projects

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Abstract

Today, mechanical engineers must know and apply the new tools of computer-aided mechanical calculation to the design and development of machines and new products. These calculation tools are fundamentally based on the Finite Element Method (FEM), and their teaching is given in the Mechanical Engineering undergraduate course “Computer-aided design”. Likewise, the subject "Calculation, Design and Testing of Machines" (CD&TM) aims to train the student on the most common elements of machines that as a future engineer can be found in his professional life. However, this subject presents a deficit in the practical application of computer-aided mechanical calculation tools, mainly due to the fact that the use of these tools is limited to only two laboratory practices, so the knowledge that students can acquire in FEM tools are reduced. Furthermore, the fact of imparting related teaching in the two aforementioned subjects, as well as in the subject "Advanced Design of Machines" can substantially affect the student's consolidation of knowledge and specific competencies of this subject. This consolidation of knowledge can be carried out through the development by students of specific final degree projects. This work shows several of the final degree projects in mechanical engineering, in which students have consolidated and consolidated their knowledge acquired in the subjects of CD&TM. These projects are a tapered roller bearing, a welded joint, and a disc brake.

Keywords: Advanced Design of Machine Elements; Calculation, Design and Testing of Machines (CD&TM); Finite Element Method (FEM); Final Degree Projects.

1 Introduction

Calculation, design and testing of machines (CD&TM) is a subject of the new curricula of the European Higher Education Area (EHEA) (Curaj, 2021), which in the old plan its teaching was taught by two subjects: Design of Machines and Testing of Machines. This subject constitutes the basis for the future engineer to develop as a professional within the field of design, construction and testing of machines, and aims for the student to acquire the theoretical foundations and develop the technical skills that allow him to assume the design and / or selection of any machine element.

CD&TM requires skills acquired in the subjects of resistance of materials, physics, mathematics, materials technology, mechanisms and above all, computer-aided design based on the Finite Element Method (FEM). In the first part of the course, the stresses are studied, both for static and variable load conditions, as well as the different failure criteria. In a second, more extensive part, different elements of commonly used machines are described and calculated: shafts, belts, gears, pulleys, brakes, welding, screws, etc. but there is no teaching given in computer design. With the final degree project, students acquire and reinforce the general competencies associated with the degree, and enable them to search, manage, organize and interpret relevant data in their area of study. Most of the times, this project or master's thesis consolidates much more the most essential aspects of certain subjects (Ull, 2009).

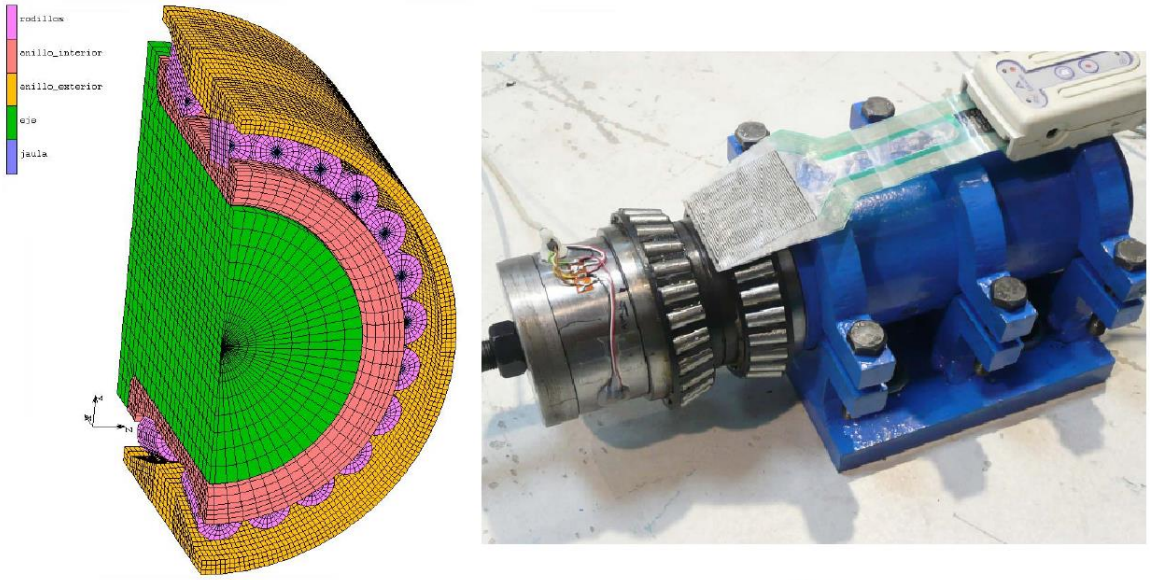
In this work, the design of various current mechanical components that students and future engineers can find in the subject CD&TM and in their future as professionals is shown. The mechanical components are a tapered roller bearing, a welded joint, and a disc brake.

2 Development of machine elements

2.1 Design of a Tapered Roller Bearing (TRB)

The importance of bearings in the design of machines leads to a search for quick and efficient calculation methods with which future engineers can estimate the behavior produced in them and understand the possible causes of failure (Shigley, 2003). Many of the failures that occur in the bearings are due to the wear that is generated in the raceways (Harris, 2007), so it is interesting to analyze the stresses that occur when the rollers contact the raceways. The main problem that exists in the analysis of TRB is that the calculation of contact pressures between two bodies presents great difficulty when one of them is not flat, since it is very difficult to predict the deformation that occurs when the elements come into contact each. In this case, the students developed a model based on the FEM to obtain the value of these contact stresses and to facilitate their design.

Figure 1: (a) FE model of the bearing (b) Experimental validation of the bearing



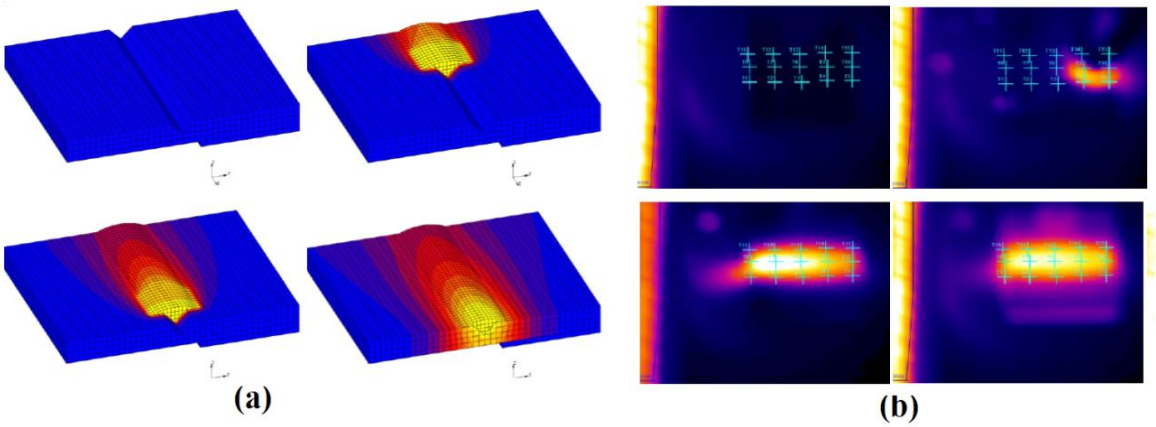
(a) (b)

The finite element model constructed was experimentally validated in the laboratory. The results obtained were quite acceptable, especially considering that the mesh size of the model required a degree of fineness that the calculation computer itself was unable to provide.

2.2 Design of a welded joint

At this point, another of the elements that are very present in machines is shown that the future engineer must know how to design and calculate. The study is focused on the prediction of the thermal behavior and at the level of deformations of a welded joint between steel plates (Reina, 1988). Through simulation with FEM, it is intended to fix the base to later recreate the process of joining by welding more complex parts. The data with which the behavior of the FE model is compared with reality are: the temperature distribution at a series of points on the joint surface during the welding process and the deformations produced after its completion due to the contraction of the metal of contribution, which will result in the lifting of the free sheet.

Figure 2: (a) FE model of the welded joint (b) Experimental validation of the welded joint with a thermal imager



The precision that has been achieved at the level of temperatures and deformations of the proposed models can be improved, although the results obtained were very good. To improve the model, the student proposed to model the welded joint with a finer mesh, that is, with a smaller element size. However, the design of this welded joint and its experimental validation is much more than enough for the student to acquire the necessary knowledge for a future design of any welded joint using the FEM.

2.3 Design of a disc brake

Since the beginning of the automotive industry, brakes have been the subject of study and research by engineers. Temperatures and stresses generated when stopping a vehicle had to be controlled and well known, so that the design of these devices makes them always work safely. The increase in temperature in the brakes is a phenomenon that is produced by the conversion of the kinetic energy of the vehicle into heat energy, affecting the load conditions on the brake itself (Muñoz, 1974). In this case, the students developed a model based on the MEF to obtain the value of the temperatures and stresses that appear when the brake operates. The experimental results were carried out on a test bench that transmitted a constant torque, obtaining results of temperatures with a thermographic camera, and of brake displacement with an inclinometer (Bhushan, 2000).

3 Skills acquired by students when completing their final degree projects

The Final Degree Project involves the individual completion of a project, report or original study under the supervision of one or more directors, in which the training content received, capacities, competencies and abilities are integrated and developed acquired during the teaching period of the Degree of Mechanical Engineering. At this point, the Skills that students have acquired with the development of these final degree assignments or final master assignments are specified. Table 1 shows a summary with the skills acquired by the students.

Table 1: Skills acquired by students in the completion of the Final Degree Projects.

Skills acquired	Bearing	Welded Joint	Disc Brake
Specific skills of the subject			

Knowledge and skills for the calculation, design and testing of machines	**X**	**X**	**X**
Generic / transversal skills			
Instrumental skills			
Capacity for analysis and synthesis	**X**	**X**	**X**
Organizational and planning skills	**X**	**X**	**X**
Oral and written communication in your own language	**X**	**X**	**X**
Oral and written communication of a foreign language	**X_1**		**X_1**
Decision making			
Personal skills			
Ability to apply knowledge to practice	**X**	**X**	**X**
Ability to learn	**X**	**X**	**X**
Adaptation to new situations			
Ability to generate new ideas (creativity)		**X_2**	**X_2**
Leadership			
Knowledge of other cultures and customs			
Specific skills of the degree			
Disciplinary Knowledge			
Knowledge of basic subjects mathematics, physics, chemistry	**X**	**X**	**X**
Knowledge in technological matters	**X**	**X**	**X**
Professional skills			
Ability to draft, sign and develop projects			**X_3**
Ability to handle specifications, regulations and standards	**X**	**X**	**X**
Ability to analyze and assess the social impact	**X**	**X**	**X**

As a general rule, the Skills acquired by the students are in all cases very similar, except in a series of points that are detailed below, which correspond to the subscripts 1,2 and 3 of Table 1.

3.1 Oral and written communication in a foreign language (X_1)

In this case, the difference in the Skills acquired in oral and written communication in a foreign language between the 3 projects presented by the students has basically consisted in the presentation of these works in a series of international congresses. These congresses have been held in collaboration with professors from the department of mechanical engineering of the University of La Rioja and the Public University of Navarra.

The Tapered Roller Bearing project and the Disc Brake project, for example, were presented and defended in English at an international conference on mechanical engineering (Ramírez, 2013; Zurrón, 2013). Furthermore, another part of the brake project was presented in Spanish at an international congress on Project Engineering (Zurrón, 2012). However, the weld seam project was presented only in Spanish at an international congress on project engineering

(Olarte, 2012). This means that the student must prepare a presentation in English and present it to a panel of experts, who question the student in English about the work done.

3.2 Ability to generate new ideas (X_2)

This Skill was widely developed, especially in the welding and brake projects, mainly due to the innovative effect of the solutions adopted by the students for the development of the FE models and their subsequent experimental validation. Thus, for example, the student who carried out the disc brake project (Zurrón, 2012) not only consisted of making an FE model of a commercial brake, but also made an improvement of this brake.

3.3 Ability to draft, sign and develop projects (X_3)

This Skill was developed solely in the brake project, mainly due to the fact that in this project a considerable improvement was made in the original design of a commercial disc brake, which meant a reduction in weight and size (Zurrón, 2012). This new design represented a substantial improvement on the original brake, as well as an execution project for a possible manufacture of the prototype.

4 Conclusions

This work shows three final degree projects carried out by undergraduate students in mechanical engineering, which have served as a consolidation of the subject Calculation, Design and Testing of Machines" (CD&TM). In addition, these works were presented and defended in English by the students in international congresses before a panel of experts on the subject, which means they have acquired the Skill "Oral and written communication in a foreign language". As a drawback, it could be said that this learning method requires monitoring and special involvement on the part of teachers and students..

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