Use of structural design and analysis software for master degree education in mechanical engineering fields

C Debeleac
Dunărea de Jos University of Galați, Engineering and Agronomy Faculty of Brăila, Călărașilor 29
Email: carmen.debeleac@ugal.ro

Abstract. In this paper the author deals a presentation of modern teaching methods applied in higher education process (master degree) at Dunarea de Jos University of Galati, Engineering and Agronomy Faculty of Braila. This paper describes main courses that are laid out in order to achieve the desired goals and how the virtual laboratory experiments should fit into the courses to promote interdisciplinary understanding. A practical example of master degree studies will be provided as a case of good practices in supporting of National education process to become harmonized with European Area of Higher Education.

1. Introduction
Nowadays, the universities must to adopt continuously their education package to be competitive and responsive to the economic environment, job markets requirements, students’ profiles and demands, taking into account by the history of their institutions [1, 2, 3, 4]. New technologies provide abundant opportunities for designing and helping to deliver a higher education curricula in compliance with labor market requirements. As a general opinion, computer-based analysis programs and computer software for design could play an important role in structural engineering education [5, 6].

This study was conducted on the branch campus of the Dunarea de Jos University of Galati, Engineering and Agronomy Faculty of Braila which delivers in Romania two-year master program (postgraduate level) with mechanical engineering curriculum to students from all over the country. In the mechanical domain, we have a professional master named Computer Assisted Analysis of Dynamics of Machines and Technological Equipment (AACDMET).

The AACDMET program provides aligned competencies with the priorities of employers, and designed to meet the needs of many specializations from mechanical engineering fields. On the other hand, the presence of some economical agents (Promex S.A., Vard Braila, Damen Shipyards Galati) in the proximity of Braila city could act as a stimulus for involve the interest students for increasing their learning ability to attendance at this master studies. Thus, staring from employers’ needs were established the six appropriate professional competencies for absolvents of AACDMET master, as:

- C1: Advanced use of the fundamental concepts of mechanical engineering fields;
- C2: Identifying and using multi-criteria principles on the choice, installation, operation and maintenance of equipment in mechanical engineering fields;
- C3: Advanced use of interdisciplinary methods and procedures specific for concurrent engineering (parametric design, modelling, numerical simulation and virtual prototyping, finite elements analysis, preparation for manufacturing);
C4: Identification and argumentation of opportunities for applying new concepts, products or technologies in mechanical engineering fields;
C5: Operating with modern systems for the acquisition and processing of experimental data using regulated methods and procedures;
C6: Innovation management with identifying the sustainability of innovative and / or process / mechanical optimization directions.

The Program's core course requirement (Table 1) was development based on these professional competencies and consists of 15 courses (with 120 ECTS credits), that can be completed through two years of full-time study.

| No | Course                                                        | Index |
|----|---------------------------------------------------------------|-------|
| 1  | Material - Equipment Interaction and Dynamic Modelling        | C-01  |
| 2  | Dynamic Analysis of Hydraulic Driving Components and Systems | C-02  |
| 3  | Nonlinear and Random Vibrations                               | C-03  |
| 4  | Computer-aided and Parametrization Geometric Modelling        | C-04  |
| 5  | Ethics and Academic Integrity                                 | C-05  |
| 6  | Structures Optimization usingFinite Elements Method           | C-06  |
| 7  | Dynamic Analysis of Handling and Transportation Machines     | C-07  |
| 8  | Computational Software for Design                             | C-08  |
| 9  | Dynamic Analysis of Vibratory and Shocks Actions Equipment   | C-09  |
| 10 | Dynamics of Embankment and Foundation Machines               | C-10  |
| 11 | Dynamics of Building Materials Recycling Machines            | C-11  |
| 12 | Experimental Procedures                                      | C-12  |
| 13 | Noise and Vibration Pollution Control                         | C-13  |
| 14 | Management of CDI Activities                                 | C-14  |
| 15 | Professional Practice                                        | C-15  |

It should be underlined that, most of the courses contains theoretical background completed with computer-aided resources based on the structural design and analysis software (e.g. CAD/CAE), such as: Matlab/Simulink (C-01), Matlab/SimHydraulics (C-02), Matlab/SimMechanics (C-10), Algor and Femap (C-06), LabWiew (C-12), SolidWork (C-04, C-08).

This paper illuminates one learning project that was given to the students for development their silks using the courses mentioned above.

2. Procedure
For final assessment, the students were asked to solve an individual project, rather more complex than the exercises given in the classroom. In this way, it forced them to follow the problem-solving process going through several stages, as following:
- problem identification;
- critical analysis of solution;
- choosing appropriate methodology to solve project requirements using computer tools.

For an example of the project, named Dynamic analysis of the behavior into wheel loader with side dump bucket will be presented some aspects performed by using the courses fulfilled at AACDMET masters’ program.

2.1. 3D drawing of the wheel loader ensemble with CAD Environment
Firstly, it was drawing the individual components of the wheel loader. The product design model of the machine consists of three main parts, as: base machine (Figure 1), Z-bar linkage equipment, and working tool (Figure 2).
Both the 3D drawing and kinematics have been performed and, respectively, analyzed in SolidWorks environment (Figure 3) based on skills learned from computer-aided modeling courses (C-04 and C-08).

2.2. **FEM analysis of the main parts of the working tool with CAE Environment**

Another step to solve requirements of the project consists of FEM analysis of the bucket in the Femap environment to highlight what stress and deformation states lead into the components in hardly working tasks during technological process. The students understand what is the structural behaviour of the bucket by identification of the mode shapes and their frequencies ($f = 10.69...62.62$ Hz and, respectively, $A = 0.105...0.242$ mm).

For example, one of the most strongly behaviour for loader working tool can be hitting with an obstacle that may occur in the penetration process in the pile of material. This task provides significant vibrations that are propagated into the metallic construction of the loader structure. Informatively, the
results obtained are shown in Figures 4 and 5. Majority of the students overall had a positive attitude toward the learning skills courses that contain digital computer technology (as C-03, C-06, C-09, C-10).

![FEM analysis results for the bucket.](image)

**Figure 4.** FEM analysis results for the bucket.

![FEM analysis results for the cylinder piston rod.](image)

**Figure 5.** FEM analysis results for the cylinder piston rod.

2.3. *Simulation of the dynamics of the hydraulic system of the mechanism for bucket manoeuvre with Matlab / SimMechanics environment*

In order to understand the phenomena that appear in the hydraulic system to manevre the bucket, when impacting it with an obstacle, students develop in the Matlab/SimHydraulic the hydraulic circuit scheme (Figure 6) which acts on the hydraulic double cylinder.

For this virtual experiment students used kinematics excitation subjected by the piston motion for mechanism movement and force sensors as feedback to the hydraulic cylinder.

![Overall view to hydraulics model of one piston using Matlab/SimHydraulics.](image)

**Figure 6.** Overall view to hydraulics model of one piston using Matlab/SimHydraulics.
The results obtained by model simulation are given in Figure 7 as terms of actuator force and error between real displacement of the piston and the command of the hydraulic control system.

![Figure 7. Simulation results.](image)

### 3. Research methodology

During the three academic years (2016/2017, 2017/2018 and 2018/2019) the author conducted empirical research on a convenience sample of master students at Engineering and Agronomy Faculty of Braila, Dunarea de Jos University of Galati who attended the course Material - Equipment Interaction and Dynamic Modelling (C-01).

The aim of this research was to investigate the students' perception of C-01 course and way of its implementation. The interviewed group varies from one year to another and the number of the involved students was: 18 (in 2016 / 2017 year), 18 (in 2017 / 2018 year) and 14 (in 2018 / 2019 year).

The author has given the questionnaire to students the course C-01 when all activities related to continuous students' assessment were finished. The questionnaire was about students’ expectations from C-01 course (content, learning activities, their engagement etc.).

### 4. Research Results

The answers of the students to the questionnaire received are centralized in Table 2.

| Question                                                                 | 2016 / 2017 year | 2017 / 2018 year | 2018 / 2019 year |
|--------------------------------------------------------------------------|------------------|------------------|------------------|
| Level of accessibility of the course                                     | Very good 22,22% | Very good 38,88% | Very good 21,43% |
| Relevance, applicability and usefulness of course content               | Excellent 77,78% | Excellent 61,12% | Excellent 78,57% |
| Clarity and degree of suitability of the projects, tasks, requirements  | Excellent 83,34% | Excellent 88,89% | Excellent 71,43% |
| relative to the course                                                   | Very good 27,77% | Very good 22,22% | Very good 21,43% |
| The degree of suitability of methods used and intellectual stimulation  | Excellent 72,23% | Excellent 77,78% | Excellent 78,57% |
| Teacher availability to provide extra time and support to students       | Very good 11,11% | Very good 22,22% | Very good 14,28% |
|                                                                          | Excellent 88,89% | Excellent 77,78% | Excellent 85,72% |

According to the students' responses, the majority of them has high satisfaction toward the learning methodology available to the C-01 course, based on the structural design and analysis software (CAD/CAE) combined with the virtual simulation software (Matlab environment).

More than 78% of students from three generations indicated that they expect the lectures abound with numerous practical examples which leads to intellectual stimulation, creativity and innovation.
5. Conclusions
Inevitably, future mechanical engineers will play an important role in growth in Romania. Therefore, the association between mechanical master studies and industrial training will be the key to providing the higher level skills that are required for economic recovery and long term prosperity.

Also, the knowledge of a powerful design software packages is an important and attractive aspect to many employers in the structural engineering field. The skills of the students to succeed in elaborating complex projects, through the comprehension of both structural analysis and design provide confidence when looking for their first job.

In this paper, the specific teaching tools as computer-aided resources were presented as good teaching practice in higher education (e.g. master level), lead to improved student learning.

References
[1] Debeleac C, Nastac S 2011 Virtual teaching environment applied to engineering science in master-level education J. of Engineering Studies and Research 17 2 49-52
[2] Hénard F, Roseveare D 2012 Fostering Quality Teaching in Higher Education: Policies and Practices, Available from: http://www.oecd.org/edu/imhe/QT%20policies%20and%20practices.pdf [Accessed 20 January 2019]
[3] High MS, Nowakowski JM 2011 AC 2011-2441: What do markets tell us about demand for engineers in the workplace? American Society for Engineering Education
[4] Kabouridis G, Georgios IG, Sotirios T 2014 Improving the skills and employability of mechanical engineering students via practical exercise World Transactions on Engineering and Technology Education 12 4 694-700
[5] Li S 2018 Innovations in Chinese engineering education with digital technologies: A brief review of recent advances Computer Applications in Engineering Education 26 5 1081-1088
[6] Manuel RL, Museros P 2002 Structural analysis education through model experiments and computer simulation J. of Professional Issues in Engineering Education & Practice 128 4 170
[7] Miron D 2018 3D Modeling and analysis of the strains into the side dump bucket Students Scientific Communications Session Dunarea de Jos University of Galati Romania