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BRIDGING THE GAP BETWEEN PRODUCT DESIGN AND PRODUCT ENGINEERING

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ABSTRACT
Product engineering is a way of designing products by using engineering skills and methods. It is often taught as a combination of mechanical, electronic and software engineering with respect to products. Product design is a more human centred approach where products are often designed from an ergonomic and aesthetic point of view.
Product development is an intermediate discipline. It combines the engineering skills with the human centred approach and relates the product with the global economical context. As a consequence product development is based on economic, human and applied sciences. Besides these disciplines a strong methodological framework is needed including what is called "methods and tools".
The paper deals with the way the curriculum at the Higher Institute of Product Development in Antwerp, Belgium, evolves towards a new more integrated approach based on the strong points of product engineering.
In the integrated approach the theoretical content is considered as a sufficient and necessary condition in order to proceed the studies. The main problem is to find a method on how to implement the integrated approach in the curriculum. The new implementation of the strength of materials course will be discussed. It will be shown that a new way of assimilation is possible and that students find the taught content very useful for the development of new products.

Keywords: education model, integrated product development

1 INTRODUCTION

Many of the design institutes worldwide can be considered as belonging to one of three possible categories: product engineering, product development and product design. Product engineering is mainly based on courses given at the faculties of applied sciences. Typical courses are: statics and dynamics of rigid bodies, strength of materials, electric motors and drives, fluid mechanics, etc. These courses are in most cases identical in all engineering disciplines. Examples of such institutes are found at Engineering Faculties in many universities. The design part of product engineering is often called industrial design. Human sciences and economic sciences are given as minors or in an additional master after master year.
Product design on the other hand is mainly based on human sciences and has a less strong engineering side. The engineering courses are mainly descriptive in nature (choice of materials, overview of mechanical components). Aesthetics together with ergonomics play a major role in the design of new products. Design for manufacturing, and assembly, is of less importance. Often, the products to design are also very diverse: from home chairs to umbrellas, from bicycle accessories to camping tents.

Sophisticated technical products requiring many verifications are no issue. Also the so-called intelligent products are of less importance in the design projects. The archetype of a product design school was found in Ulm, Germany.

Product development is an intermediate discipline where the product as a whole is the central part of the learning process. Besides the engineering approach, addressing the product from the human centred and the economic point of view are also important. Design methodology is the steering issue of the development process. If product development is based on the four named disciplines then the development process is called integrated product development. The Higher Institute of Integrated Product Development in Antwerp, Belgium is a good example of this category of design schools.

The three described approaches are of equal importance and result in strong products although the help of additional and intermediate disciplines is not evenly distributed over the three disciplines. And this is of course the result of the different "styles" in education.

2 MAKING A SCHEME OF THE DIFFERENT APPROACHES

Figure 1 shows a general view of the integrated product development approach during the education of design students. One figure is available for every bachelor or master year.

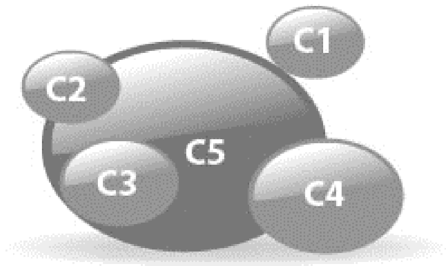

Figure 1 General scheme of integrated product development

The large central circle C5 represents the product development process (PDP). The smaller circles contribute to this process. These circles represent courses out of the four disciplines: applied sciences, human sciences, economic sciences and methodology of the product development process. If a smaller circle (figure 1 - C1) lies completely outside the large circle then the content of the course does not contribute in a direct way to the PDP. Examples are courses on photography and web design. A circle (C3) that lies within the larger circle is completely useful for the application or the understanding of some aspect of the product development process. Methodology courses normally lie completely in the large circle. The radius of the circles represents the volume of the course in ECTS equivalents. A circle (C2 and C4) that partially lies inside and outside the large circle represents a course where only a part is very relevant to the PDP. Possibly some theoretical background is needed before more explicit references are made to the PDP. An overview figure can also be made: only one circle for the complete group of applied sciences courses is then drawn and similar circles are drawn for the human, the economic sciences and one circle for the methods and tools courses.

2.1 Engineering design

Let us now make a scheme of the engineering design curriculum (see figure 2). In this approach the diameter of the applied sciences circle is larger than the diameters of the other circles. There is also an overlap with the PDP circle. In some faculties of industrial design the applied sciences courses are the same as those given for the other engineers. In this case the overlap with the PDP circles is rather small: these courses are very general in nature and do not contribute to the typical industrial design attitude.

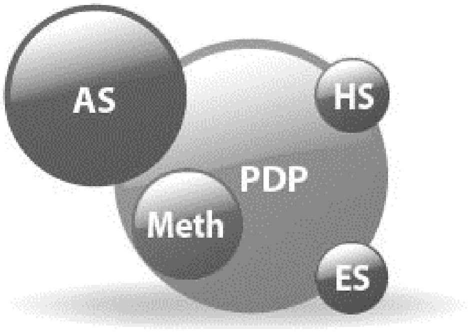

Figure 2 Engineering design

An example is the course of electrical machines: the average designer only has to know the more familiar motors used in small designs, robots and home appliances. The chance that he/she will ever use three-phase motors, and generators is rather small. DC servo motors and stepper motors, and the way they are driven, have to be known rather thoroughly. The same is true for strength of materials courses. The engineering approach is not very useful for design students. Designers are very often faced with frames rather than with beams or trusses. Moreover, in 90% of the design cases the problem is statically undefined. This makes an engineering approach, as taught in many courses, not applicable. The same remark is true for many other engineering disciplines.

The design part of the curriculum is limited to the methods and tools circle. In the methods and tools courses the students learn how to make drawings, sketches, and get general knowledge on how to establish an engineering design trajectory. The human sciences circle is mostly limited to the ergonomics course and the economic sciences circle is also very small. In many engineering design schools design engineers are just another group of engineers, next to electrical, structural, mechanical and manufacturing engineers.

It is clear that this approach has the advantage of being very thorough but it lacks many disciplines of the product design approach, and it also lacks the knowledge on how to manage the product development process. The question is: how do we manage to implement the strong engineering aspects in the product development approach?

2.2 Product design

The scheme for the product design curriculum looks completely different (see figure 3). Now the applied sciences circle is rather small and the methods and tools circle is the largest. The human sciences circle is larger than in the previous scheme. Examples of human sciences courses that are taught are history of ... courses, psychology, aesthetics, etc. The applied sciences courses are mostly restricted to material sciences and some general and basic physics. The design projects are very centred on form and shape. Furniture and interior design are also part of the exercises. Intelligent products are designed from a pure human centred point of view. Interaction design is also very prominent. Thermal and structural verification are nearly completely absent. Verification of electronic aspects (e.g. the use of new input devices) is also lacking and cost calculations are impossible to make.

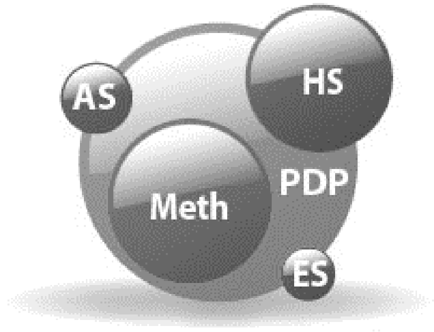

Figure 3 Product design

The two most important shortcomings are: the management of the product development process is not part of the curriculum and also there is no profound knowledge on how to make essential engineering verifications.

2.3 Integrated product development

The ideal scheme is shown on figure 4. This scheme bridges the gap between product design and engineering design. Three of the four involved disciplines overlap the larger PDP circle with the larger part being inside the circle. The applied sciences and design methodology circles have a larger share than the human sciences and economic sciences. The methods and tools circle, now called the design methodology circle, is smaller than in the product design curriculum because less attention is given to courses like graphical design, web design, ... The main focus lies on the management of the product development process. Different courses on management techniques are essential.

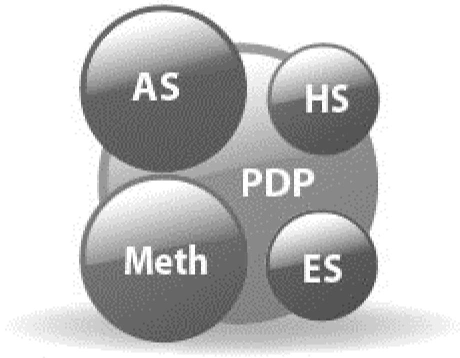

Figure 4 Integrated product development

The next paragraph deals with the way the applied sciences circle is organised more efficiently within the PDP and how verification techniques are implemented in the curriculum.

3 EXAMPLE OF THE NEW APPROACH: STRENGTH OF MATERIALS

How the applied sciences courses are taught is shown by taking one example course: the strength of material course. This course is essentially based on the statics course. Important topics are: free body diagrams, degrees of freedom, support forces, internal forces in beams and the associated stresses, stress criteria (von Mises criterion), choice of materials, safety factors. In engineering design this theory is mainly explained by using beams and trusses. Single beams and trusses are very important for structural engineers but 90% of the practical cases are frames where the loads may be applied on the beam itself. 90% of all problems are also statically undefined. This complicates the verification enormously. Normally statically undefined beams and constructions are not treated in too much detail. Only in a small number of cases practical problems can be solved by using advanced methods.

We have chosen for an implementation of finite element software. Doing this brings the course into the larger PDP circle. There are many excellent software programs (demo/trial versions with/without limited number of freedoms) that can be freely downloaded from the Internet [1]. Many of these programs are excellent in bridging the gap between product design and engineering design. It is however necessary that the student also knows the process behind the finite element method: minimizing the energy of a system consisting of beams and loads.

The strength of materials course at our institute starts by explaining how to solve all previous exercises from the statics course by using a finite element program. Essentially in the statics course is the understanding of a free body diagram. Drawing a free body diagram is as essential for a designer as his sketching skills. Solving the equilibrium equations is the next step. Showing that the solution of these equations gives exactly the same results as the finite element program shows is the next important move. It is a very satisfying feeling to know that almost any problem, however complex it may be, may now be solved by little effort.

The next thing to show is that software is the ideal tool to verify more complex design problems. Therefore a frame is taken as an example. The bicycle example is ideal for this purpose. Forces can now be applied on every point of the frame. No further need to use trusses any more and no need to apply the loads on the connecting hinges. All internal beam forces (axial, bending, transversal, torsional) and deflections can now be calculated and discussed. This is the moment where stresses come into the world of the designer. Stresses are derived from the internal forces. All relevant stresses can now be simulated by using appropriate load conditions. A combination of these stresses (the von Mises stress) can now be used to compare with relevant material data. A complete design made up of frames can now be verified in a very professional way. Moreover, different materials and different cross sections may be used in the same structure. All geometrical modifications of the basic structure can now be verified. New designs are very easily drawn and verified. The strength of materials course has now become a design tool instead of a rather abstract piece of theory.

4 CONCLUSIONS

By using the strength of material course as an example, it has been shown that applied sciences courses can be adapted in this way that they bridge the gap between the engineering design approach and the product design approach. The course has become a design tool rather than an abstract and difficult to use instrument. The course is now almost completely integrated within the entire product development process. This approach can also be extrapolated to the other courses within the applied sciences circle and gives added value to the integrated product development designers [2].

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