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Virtual Product Development Process in Education of Mechanical Engineer

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***Abstract*— Design, manufacturing, and product development is the complete set of activities needed to bring new devices and technologies to the marketplace. These activities span the entire product life-cycle, from the identification of a market opportunity or need, through design, testing, manufacture and distribution, and end of useful life. Product development manages the creation of the product itself, under the consideration of different boundary conditions.**

In this way, product development processes include all of the operations necessary to bring a new product to market. This includes the idea generation, the concept phase, product styling and design and detail engineering, all of which are conducted in the context of market research and marketing analysis.

In future all mechanical engineers in virtual process of product development area must be competent in two things: the use of computers for 3D design concepts, modelling, analysis and visualization as well as interacting in a complex environment of multidisciplinary (engineering) groups. Education mechanical engineers of Mechanical Engineering, University of Nis Department of mechanical design, development and engineering in this direction was organized.

***Key words*— Virtual Product Development, CAD, CAE, RP**

I. INTRODUCTION

Product design is often misunderstood as a concept. It is commonly seen, as the process of making products look aesthetically pleasing or stylish. Most product designers understand product design to mean much more than this. Product design is a multi-disciplinary process which usually involves market and technological research, concept design, prototype development, final product development and testing as well as post production refinement. Product Design is defined by Walsh et al (1992: 18) as: "The *activity in which ideas and needs are given physical form, initially as solution concepts and then as a specific configuration or arrangement of elements, materials and components*".

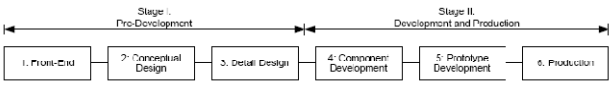

Fig. 1 Six phases of NPD

"New product development (NPD) has long been recognized as one of the corporate core functions. During the past 25 years, new product development has increasingly been recognized as a critical factor in ensuring the continued existence of firms. The rate of market and technological changes has accelerated in the past years and this turbulent environment requires new methods and techniques to bring successful new products to the marketplace. IT improves NPD flexibility. New product development requires the collaboration of new product team members both within and outside the firm." [6].

Rainey (2005) describes integrated product development (IPD) as "a strategy that integrates all activities from product concept through to production. IPD is a multidisciplinary management strategy that uses product teams and design tools such as modelling and simulation teams to develop products and processes to meet cost and performance objectives concurrently.

IPD involves understanding the customer's needs and managing those requirements together with,

- suppliers as partners,
- integrating product development and research and development with the business strategy and business plans,
- integrating the design of manufacturing and product support processes and managing cost from the start by effective planning,
- low-risk development and managing project scope.

The NPD process begins with an idea to build a product that meets specific needs (or create new needs for radically innovative products) defined by customers and/or the manufacturer, and ends when the product is launched on the market. This involves six phases as illustrated in Figure 1.

These six phases can be grouped into two stages (Stages I and II).

Stage I, the *predevelopment stage* consist of three first phases and is concerned with a *nonphysical* (or abstract) conceptualization of the product with increasing levels of detail.

Stage II, the *development and production stage,* consists of the next three phases and deals with the *physical* embodiment of the product resulting from the transformation of the conceptual product into a physical entity.

II. Tools and Methods for Virtual Product Development Process

Virtual product development includes all IT-supported, virtual product-model-based processes for the generation of a new product. Virtual product models are used to perform optimization and testing procedures in a virtual environment with the goal of saving development time and costs, while simultaneously increasing the product quality. Depending on the categories of development applied, there are different types of virtual models. They can include market-relevant or business-case-relevant data (economic models), workflow-oriented information (process models), technical characteristics and descriptions (functional models), and geometry.

Representative of these types of systems are Computer-Aided Design systems (CAD), which form the core element of digital product development.

"Today, the Computer-Aided Design (CAD) industry is a multi-billion dollar business with literally millions of engineers, architects, and drafters using these computer systems on a daily basis. The technology has clearly changed how many professions are practiced, predominately, but not in all cases for the better. [7] CAD systems are surrounded by Computer-Aided Engineering systems (CAE), i.e. Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD) or Digital Mock-up (DMU), by Computer Aided Industrial Design systems information (design models). Depending on the different requirements and characteristics of diverse disciplines, both the virtual models and the results generated can differ significantly. In general, the disciplines of virtual product development can be classified into main groups [3].

Figure 2 roughly shows a map of tools and methods for product development over the design process and product life-cycle. While some of them originated in 1970s, others were formed in 1990s or later under the movement of concurrent engineering. The coverage of tools and methods has been gradually spread so as to support a series of phases and aspects more widely and in more integrated way. When considering that product development is an integrated activity, it should be an essentially important view not only to utilize respective ones, each of which was developed independently from the others, individually but also to systematically organize the overall process of product development by selectively utilizes ones, which are necessary and effective for a specific project, from available ones.

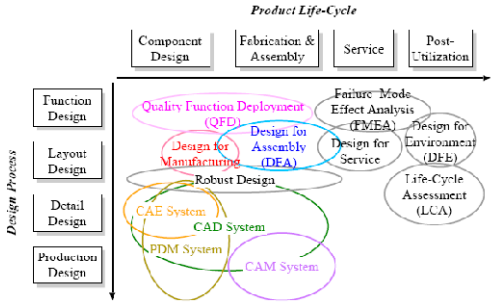

Fig. 2 Design process and Product Life - Cycle

(CAID) for initial form finding or Virtual Reality (VR) for design reviews and immersive interactions. Data administration is controlled by Product Lifecycle Management (PLM) or Collaborative Product Commerce (CPC) systems which also manage the flow of electronic data throughout the entire life cycle of the product and which interact with enterprise resource planning systems (ERP).

CAD is used to create a geometrical product representation within a virtual environment. CAE includes a wide range of product calculation, simulation, optimization and planning processes in several disciplines (e.g. mechanics, electrics, electronics, optics), which are performed parallel to the geometry creation. Of course, throughout the virtual development cycle, design always goes hand in hand with computational engineering processes. In some literature, virtual development in general is denoted as CAx (computer aided technologies).

The combination of different CAD and CAE processes can be displayed as process chains.

The following sections include a short introduction of typical CAD-CAE workflows.

Based on a selection of typical automotive development processes, a short description of the main targets, applied procedures and data formats provides an overview of virtual-development-related tasks (Fig. 3). Different CAE applications are based on a 3D CAD master model, which serves as a data source. Depending on the data format and accuracy required, the geometrical product information is converted and transferred into the CAE environment. The black arrows indicate a direct data connection from the CAD system to the corresponding CAE process.

The information backflow after the evaluation and verification of simulation results always represents an important task in efficient development cycles (dotted arrows).

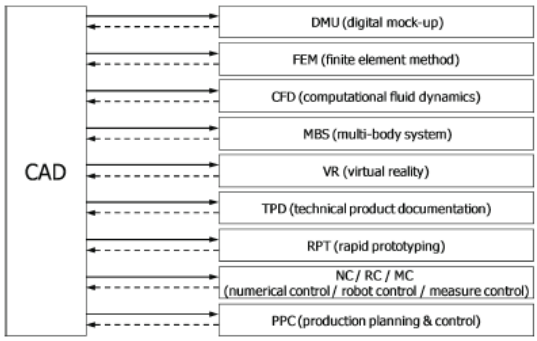

Fig. 3 Examples of CAD-CAE workflows

The finite elements method is used to calculate stress, deformation, thermal load, structural dynamics or NVH (noise, vibration and harshness). The FEM separates the continuum into finite, simple areas or volumes (finite elements), which are connected at defined nodes (mathematical discretization). FEM calculation processes are based on approximated geometries, derived from a 3D CAD model.

Multi-body simulation is used for the kinematic and dynamic calculation and optimization of assembled (movable) parts. MBS models are based on general geometrical definitions in CAD product structures.

Virtual reality and augmented reality generate virtual environments as real-time simulations for product representation and product-related investigations. They partially incorporate the user in virtual surroundings and

product-related operations. AR functionalities enable the implementation of additional information and data into a VR environment.

Technical product documentation enables the derivation of technical drawings, bills of material, spare-part lists, prospects, and other items directly from the 3D CAD model.

Rapid prototyping is used to generate hardware models from virtual geometry data during the product development phase. Such prototypes, which are available at an early stage, enable real-life studies, test bench optimization or customer discussions.

RPT is used for concept models, design or ergonomic studies, or functional tests and optimization. Rapid prototypes are generated from tessellated geometries, which are derived from 3D CAD master models. The most common file format is STL (structural triangle language). STL geometries are calculated via triangulated surfaces with no design history or product structure information. RPT production techniques include laser sintering, stereo lithographic, 3D-printing and others.

Industrial development processes have included methods for collaborating strategies for many years. More powerful IT systems and the capabilities of virtual engineering and data management have supported an increase of data exchange and have opened up new ways of collaborating.

III. Education in Field of Virtual Product Development in Faculty of Mechanical Engineering

The Karlsruhe Education Model for Product Development KaLeP was introduced in the year 1999 at the Institute for Product Development, University of Karlsruhe (IPEK), and since then further advanced. In year 2005 it is introduced at Faculties of Mechanical Engineering in Balkan countries where it takes into account cultural and social characteristics of Balkans Countries region and previous experience in product development education. Implementation of new education model was preformed through several subjects related to product development education already existing in the curriculum of Mechanical Engineering Faculty, University of Nis since year 2005.

KaLeP is based on three approaches for imparting the taught knowledge in a possibly practicable form: the teaching units of the courses are divided into the three parts lecture, practice/workshop, and project work. This measure enables the effective teaching of theoretical matter (lecture), the demonstration of its application in example and practice (practice/workshop) and the intensive practice of the realistic work (project work).[18]

During five year of KaLeP implementation at Faculty of Mechanical Engineering in Nis was made five cycles of student development projects which develop 11 new products. In development project participated 12 student teams with 107 members. Product development tasks were defined by companies like:

- Alfred Kärcher, Germany
- AMIGA, Kraljevo
- PROFIT, Niš
- Elektromedicina, Niš
- Resor, Gadžin Han

Goal of this student product development projects were to make prototype or to make documentation for production of prototype for products that can be launched on a market. An important phase for development of such products is Virtual product development.

Product profile was defined by analysing technical and economical parameters. Next step - technical design of all necessary parts, subassemblies and assemblies are made in design phase by using 3D software which make it possible to make documentation in relatively short period. Fig 4 shows 3D model of device for washing/disinfection that is used in health care (product task was given by company Elektromedicina – Nis).

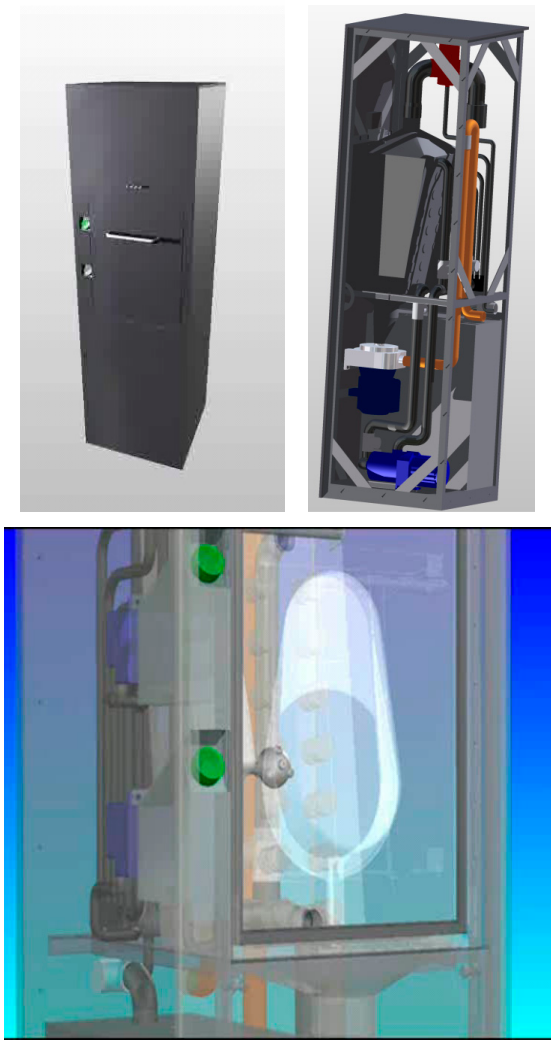

Fig. 4 3D model of developed device for washing/disinfection

In some cases, where it was necessary, students were using FEM programs to solve the product development problems by not making expencive testing.

German company Alfred Kärcher define product development task of making innovative product by using UV-C lamp. One of the effects of UV-C lamp in water is to kill bacteria and it known that by using UV-C lamp is possible to clean water. The main problem of this effect is low efficiency of UV-C lamp. Product development task was to make product solution that can increase efficiency of using UV-C lamp. This is possible by increasing the temperature or using high flow of water around the lamp. Students come to numerous ideas but selection the right idea for the proof of concept was problematically while

they need to have comparable simulation results before they made the idea selection.

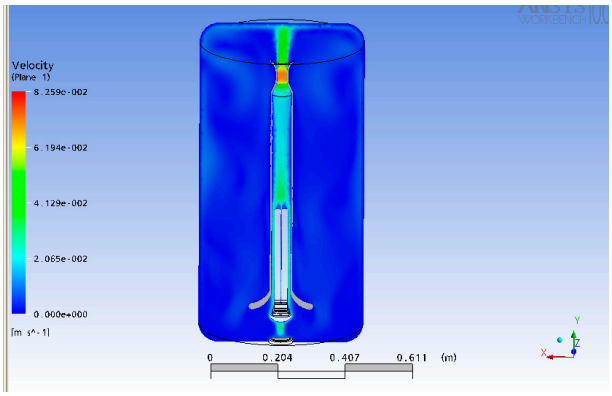

Fig. 5 Simulation of streamline velocities in the tank

Using simulation programs they were able to simulate product ideas in short period and to come to results that can be compared. For example, streamline velocities inside main tank was simulated by using CFD (Compute Fluid Dynamics) method (Figure 5).

Beside KaLeP, Virtual product development is implemented and strongly used in various subjects at Faculty of Mechnical Engineering. Students learn how to use 3D modeling programs as well as to simulate using FEM (example Fig 6).

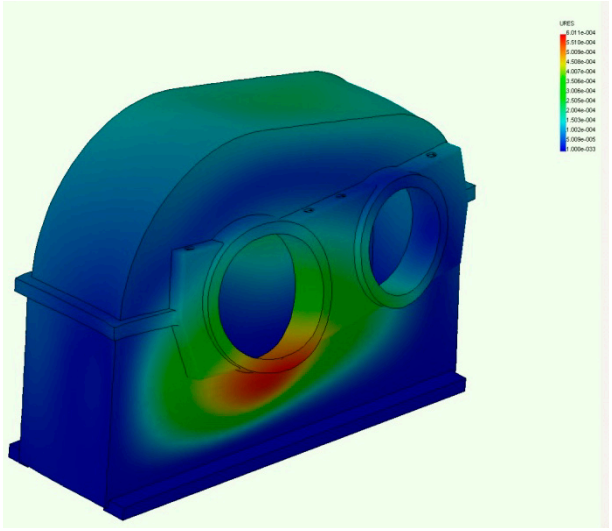

Fig. 6 Finite elements analysis –deformations on the power reducer's case

Subjects with integrated use of 3D modeling or FEM:

- Virtual product development
- Computer added product development
- Basics of Product development
- Product development methods
- Design

Department for mechanical design, development and engineering has received in year 2015 3D printer EnvisionTEC ULTRA® 3SP which can print 3D model functional parts of high resolution (Voxel Resolution in X and Y 50 µm) using stereolitography method (Figure 7). Printer was received via Tempus project IPROD (Improvement of Product Development Studies in Serbia and Bosnia and Herzegovina) which coordinator was University of Nis and it was realised on Department for mechanical design, development and engineering.

It has also virtual infrastructure which is designed for users to have approach from out of Faculty whenever they want. This virtual infrastructure has all the necessary licenced software that is needed for student work. Work on virtual infrastructure has proven to be much better while all the students have equal approach to the hardware that has superior performance and provide pleasant work with demanding software. Every student has account and the only demand for them is to have internet access.

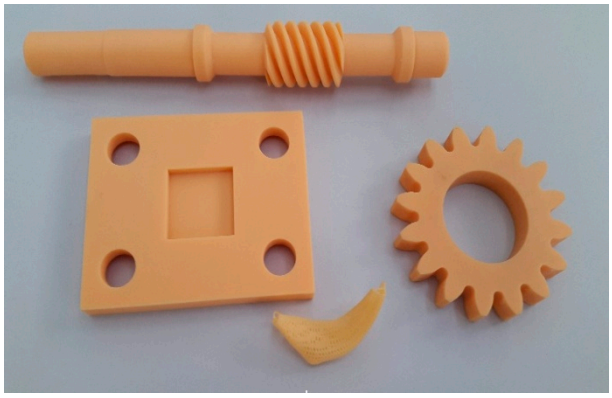

Fig. 7 Parts printed with EnvisionTEC ULTRA® 3SP

Student Marko Ristić was awarded prestige prize "Petar Damjanović" by „Osa računarski inženjering" Company for the best graduate thesis in Product Development for his work made in Autodesktop Inventor in year 2010 (Figure 8).

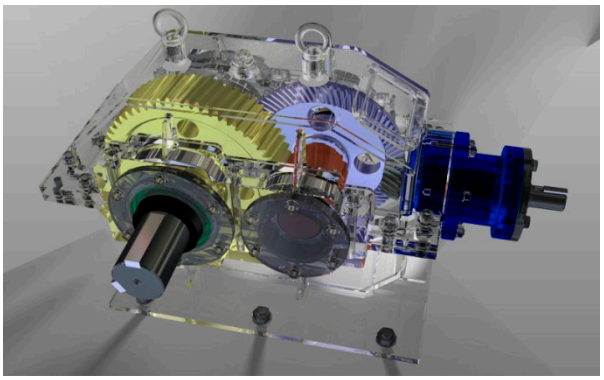

Fig. 8 Combined power transmission - helical gear pair and bevel gear pair

Student Nikola Lazic was awarded prize "Petar Damjanović" by „Osa računarski inženjering" Company in year 2013.

IV. Conclusion

Modern industrial age delivered new demands to the enterprises on product development:

- need for the fast product development,
- reduction of time and costs in order to stay competitive
- on the market, and
- increase of quality.

In future all mechanical engineers in virtual process of product development area must be competent in two things: the use of computers for 3D design concepts, modelling, analysis and visualization as well as interacting in a complex environment of multidisciplinary (engineering) groups. Education of mechanical engineers

in virtual process of product development is organized at Faculty of Mechanical Engineering, University of Nis - Department of mechanical design, development and engineering. Within the Tempus project IPROD (Improvement of Product Development Studies in Serbia and Bosnia and Herzegovina) which coordinator was University of Nis and it was realised on Department for mechanical design, development and engineering, new equipment was obtained on which will be train a new generation of students in the area of virtual product development.

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