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Integrated Design at VIDA Centre Poland

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Abstract
The modern design process forces the tight integration of processes connected with the development of the product. All the steps of the design process are based on geometrical models created in CAD systems. The geometry of the product is used for programming of the virtual environment of the product, its behaviour, manufacturing and so on. It is necessary to remember that the integrated design process needs special skills and knowledge from engineers. The authors of this paper presented a brief description of the VIDA Centre at Poznań University of Technology, its structure and skills in the area of integrated design. Couples of examples of projects realized at VIDA Centre's environment as integrated design of products are described as well.

Keywords:
Product Development, Integrated Design, VIDA Centre's environment, VIDA skills in integrated design

1 INTRODUCTION

Nowadays, product design is understood more as a product development during the whole life cycle (Fig. 1). The design should take into consideration all the stages of the product life cycle: its manufacturing, exploitation, recycling and so on. These force the integration of all processes into product development. Product development forces the use of new design methods as well as methods for managing a design process.

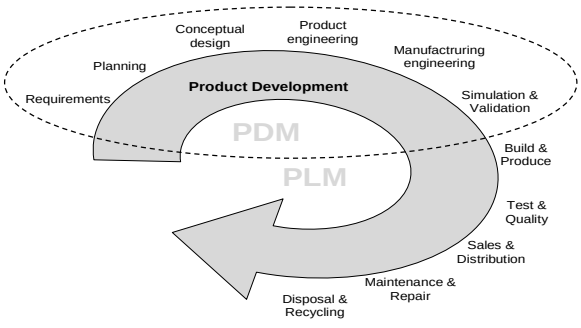

Figure 1: Integrated product development

New product development embraces all stages including the defining of requirements, product planning, conceptual design, product engineering, manufacturing engineering, product and process simulation and validation, all the way up to the realization of production.

To manage the integrated design process the PDM/PLM (Product Data Management/Product Life Cycle Management) system is becoming more common.

The product development is based on virtual model of product and on virtual method used for its research, testing, simulation, description and all activities necessary for its production and is named Virtual Product Development.

Virtual Product Development can be considered as a complete set of activities that are necessary to bring new devices, technologies, and services to the marketplace. These activities span the entire product life-cycle from the identification of a market opportunity or need, through design, prototyping, testing, manufacturing and distribution, and end of product life.

The application of computer technologies enables virtual product design that incorporates all the stages of the product life cycle, from product and production planning, through the creation of prototypes, the modification of its geometry and its functionality, the simulation of manufacturing (machining and assembly), its automation and determination of production costs.

Product creation processes are increasingly performed digitally to reduce the numbers of hard prototypes. This approach results from the need for increased flexibility and a faster response to the market. To develop a product, VR (Virtual Reality) technology is used more and more often. Using VR technology to develop a product sometimes involves the designer importing the geometrical model from different CAD systems. A Digital Mock Up for an analysis of the behaviour of the product may also be used. Reliable communication system between designers working at different work stations is the crucial point in this approach. Often for managing the whole design process a PDM system is used.

A PDM system enables to organize the team working within the framework of a particular project and reflects the structure of the organization (team and its members) and the roles of particular members within the team and project (i.e. designer, approver, etc.). This may be achieved mainly by user management functionality. Specific for PDM systems are data and document management function that ensure the mirroring of the process characteristics for design (i.e. the approval or rejection of a document or a project's stage). The product is developed during its whole life cycle but the main development stage takes place during the design process. The PDM system is designed mainly for the management of documentation that may appear during work on the product and for the management of work

flow, but the PLM system also embraces the other life cycle phases.

The integration of product development creates interaction and overlap between the stages in the whole product development process and it is mainly achieved by:

- enhancement of new product development process,
- variety of product definition,
- organizational context,
- teaming.

Integration can be perceived on three main levels. The basic layer concerns data, where it is ensured that the output data from the result of one stage in the product development and the input data for the next stage are of appropriate and compatible formats. The second layer is related to the tools based (mainly) on the computer tools being used in the activities at a particular stage of the process (mainly systems belonging to the CAx group) as well as tools that enable communication within the team. On the third, top layer, are the methods used in the process to ensure that resources are used as effectively and efficiently as possible. Methods should be assessed to ensure they are prepared in order to achieve maximum benefits by the team.

2 PUT AS ENVIRONMENT FOR VIDA CENTRE

The PUT (Poznań University of Technology) research and development activities encompass the broad area of machine tool design and related manufacturing processes, as seen from the perspective that spans the whole product life cycle. PUT has a long tradition in machine tools design and their automation. It holds significant achievements as well as highly qualified personnel in this field. The information technologies for machines design process are used at PUT effectively for almost 20 last years. Numerous software systems, from CAD, CAD/CAM, CAPP, FEM, PPC together with production simulation systems are used at PUT. Institutes have numerous computer stands and well organized and equipped computer laboratories. The existing computer systems allow for virtual product design, starting from the stage of product and production planning through prototyping, geometric characteristics modification, fitness for use creation to manufacturing (e.g. machining and assembly) processes simulation and manufacturing costs computation. Nevertheless, in many cases, it is required to purchase new software or to upgrade the versions of the software or to work out the interfaces. The infrastructure of PUT was developed within the confines of several national projects (founded by Polish Science Committee) and European projects (founded by Tempus, Copernicus, Inco-Copernicus Programmes).

The PUT has specific contributions to the advancement of the understanding the scientific and technological problems to be solved in home country. The many investigations have been made in cooperation with home country enterprises and with others universities. The results of research have made an important contribution to development of Polish science and industrial practice in the following areas:

- design, automation and investigations of different machines and equipment,
- machine design methodology, its optimisation, CAD and FEM,
- mechatronics, automation of machines,
- forming and possible application of modified face toothing,
- fluid power technology, especially hydraulic linear drives,
- planning of modern machining technologies and CAM,
- robotics and montage planning,
- assembly and disassembly with regard of recycling,
- production process planning, control and management,
- machining and its diagnostic,
- new cutting tools design and their investigations,
- application of CAD, CAPP, CAD/CAP and PPC in industry,
- flexible manufacturing systems and CIM,
- design of production quality control systems,
- design of metrology and diagnostic systems in mechanical enterprises,
- automation of measurement and monitoring,
- modelling and simulation of production capacity of products (machines, apparatus and devices) in range of assembly and disassembly with regard of recycling,
- planning of modern machining technologies for machine elements taking into consideration costs of its realization,
- practical applications of industrial information system.

In the area of Poznań there are many mechanical enterprises and small and medium companies. PUT is especially focused on cooperation with those companies and their area of interests.

The research groups of PUT for several years co-operate with numerous industrial enterprises in Poland, especially in Poznań City and Wielkopolska region. There are numerous amount of enterprises in Poznan and its nearby terrain, representing the following industrial branches: automotive industry (VW Poznań, MAN companies), motor industry (HCP Poznań Company), furniture industry (in Swarzedz and Oborniki cities), plastics industry (Wavin Buk Company), chemical industry (Beiersdorf-Lechia Company), food industry (Lech Browary Company), machine tools and machine equipment industry (JAFO, FAMOT companies), building industry (Metalplast Company in Poznań and in Oborniki Wielkopolskie).

The VIDA Centre, which is described in the next chapter, exploits the infrastructure that has been prepared so far. Joint of individuals laboratories (research areas) by usage of Internet technology and state-of-the-art information technology in data and processes management allow to make the data available and to exchange the data generated within the next phases of product design and manufacturing processes development. It is the platform to join the VIDA Centre with other centres through networking. Such solution will also make easier to join the European research area and will allow the Institute to become a partner within the Framework Programme.

3 SCOPE OF DESIGN IN VIDA CENTRE

The concept of creating VIDA was a consequence of the so far development of the Poznań University of Technology. The VIDA Centre integrated several stages of product and process design and enabled demonstration of the integrated design process as a whole as well as the selected steps only, if required. Connecting several laboratories of PUT over the Intranet and application of the cutting edge information technologies in the field of design, data, and process

management has resulted in sharing fully the information generated at the subsequent steps of product and process design.

The organizational structure of the VIDA Centre is based on the structure of the Faculty of Mechanical Engineering and Management. The working groups are completed in dependence of current realized projects.

The VIDA includes the following aspects that are innovative in comparison with current state of the research:

- Intranet is fully used to integrate the design process,
- design is based on the virtual model of a product and manufacturing process,
- a comprehensive demonstration of design process and its constituent elements is possible in virtual reality .environment,
- new or emerging design and information technology is used, such as rapid prototyping, rapid tooling, DMU.
- deep integration of the VIDA Centre with other centres will be possible thanks to usage of appropriate common software platform.

The environment of VIDA can allow designers to digitally define and evolve product models in a more natural manner and that will provide designers with the implicit, intuitive methods for expressing and evolving their projects. Designers at the VIDA Centre are able to use the latest, up-to-date tools for CAD/CAM/CAE modelling, Virtual Reality, Virtual Prototyping, Reverse Engineering, Rapid Prototyping and Rapid Tooling methods.

A virtual product created within the VIDA centre can enable the real-time visualization and review of the 3D product as it evolves, thereby will streamline a collaborative review and decision-making and driving innovation. The DMU can allow design teams to digitally build the product prototype and its environment, and then analyze it to gain an early insight into the key factors determining design quality, product performance, and ultimate market success.

The VIDA environment can provide extensive support for industry. Using Rapid Prototyping and Simulating tools for testing and analysis can reduce and even eliminate the time and cost invested in build it / break it scenarios requiring multiple real prototypes. Reverse engineering technologies can be used for transforming hand-made design into virtual reality and for the reconstruction of lost design knowledge from previous designed products. Rapid Tooling and Rapid Manufacturing tools will shorten the time to market for short series products.

VIDA also is able to disseminate the innovative technologies in the area of virtual product and process development in trainings. Worked out special applications that support the data management tool and the planning of manufacturing operations are based on the recorded knowledge rules.

VIDA is involved in research in the area of Virtual Product Development on regional, national and European level supported by a video-conferencing system.

On the regional level, VIDA cooperates with SMEs and manufacturing clusters, disseminate the result of projects and exchange the know-how and experience in cooperation with the Wielkopolska Chamber of Industry and Commerce.

On the national level, VIDA Centre cooperates with the Polish Network SDPP/ProNet (Network of Excellence of Production Processes) and other Polish Technological Platforms.

On the European level, the VIDA Centre is incorporated into the international research activities in the framework of the European Research Area (as well as in Technological Platforms) through the EMIRAcle Research Association (earlier EU NoE VRL-KCiP).

The collaborative design environment of VIDA is based on PDM system as a management system for supervision of design process and information flow. The PDM system enable preparation of the system towards particular project's needs – it encompasses definition of users, groups, permissions, etc. reflecting roles and functions of the persons involved in the project, definition of project's stages, tasks within them, persons to whom these element will be ascribed, input and output data and time constraints.

Nowadays within the frames of VIDA there are working groups in following domains: 3D Modelling and Reverse Engineering, VR (Virtual Reality), Design for Manufacturing, Design for Assembly and Disassembly, Design for Recycling, Rapid Prototyping and Rapid Tooling, Production Planning and Simulation, Virtual Engineering, Design of Drive and Control systems and Quality Engineering (Fig. 2).

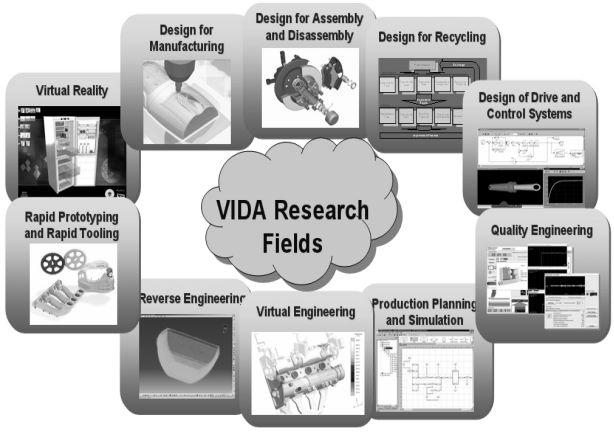

Figure 2: VIDA research area in design

CAD modelling is an important step in a new-product design that is base for a further design and applications. The 3D modelling in CAD/CAM systems (i.e. CATIA, ProEngineer, IDEAS) is developed in connection within research in Rapid Prototyping, Reverse Engineering, Virtual Engineering and Virtual Reality applications. The CAD models are used for programming of manufacturing, assembling, disassembling processes and simulation of these processes too.

In the area of production planning and simulation the modelling and simulation of workstations layout, modelling and simulation of material and information flow and visualization of manufacturing processes were developed. The Artificial Intelligence methods and Computer Aided Process Planning systems are used in this field.

The VIDA carries out research of assembly sequence of machine parts and sets using the graph theory, analysis and investigation the technological ability of construction of part, sets and whole product, using the theory of Petri Nets, heuristic and genetic algorithms to balancing assembly line, designing for automated and robotized operation of assembly and disassembly, and investigation of CAx systems to designing of assembly structure and simulation assembly processes.

In the domain of Virtual Engineering the use of Virtual Prototyping techniques for casting and plastic working was developed. The research addresses the problems of simulation systems application for modelling of mass and heat transfer, and microstructure modelling.

Research in the domain of design of drive and control systems concerns on:

- control of electro hydraulic servo drives and modelling of electro hydraulic servo drives and mechatronic devices,
- applications of magneto-rheological fluids,
- linear and rotary dampers,
- applications of artificial intelligence in control,
- automation of technological machines and processes,
- magneto-rheological shock and energy absorbers,
- electronic controllers of devices with magneto-rheological fluid.

In the area of Quality Engineering the following domains are investigated:

- the methodology for product design and process planning oriented towards quality,
- usage of methods and tools for quality improvement,
- data processing for quality control e.g. patterns classification on control charts based on artificial intelligence (AI) methods and neural networks,
- development of data model for quality methods and tools integration,
- process – oriented information flow modelling for quality control circles in enterprise,
- quality systems audits,
- measurement systems design and analysis.

4 VIDA COLLABORATION PLATFORM FOR INTEGRATED DESIGN

Integration processes during design in VIDA proceed on four levels:

- organizational, consisting of the structure of particular teams within the sphere of development project: their members (designers) and the roles played by individuals during the design process,
- data, based on a choice of document (file) format which is suitable for all participants,
- methods of product development, according to standard
- tools, perceived mainly as a common collaboration platform (the tools and methods for collaboration), guidelines, eg. VDI-Richtlinen or Lemach.

The collaboration platform (Fig. 3) enables:

- the organization of the team working within the framework of a particular project,
- reflect the structure of an organization (teams and their members),
- the simultaneous execution of different projects,
- reflect the roles of particular members within the team and project (i.e. designer, approver, etc.),
- reflect the characteristics of design information systems (i.e. approval or rejection of documents or project stages),
- aid in the utilisation of documents of different kinds and formats,
- use already existing IT infrastructures (Intranet),
- encourage the speedy implementation of project work within the system,
- organize data access and documents management in relation to the project,
- manage workflows,
- reflect the methods of particular team members (work within the established environment should be as close as possible to the already existing methods and tools),
- ensure the mechanism for data classification and search,
- deliver common services of data transfer between design stands.

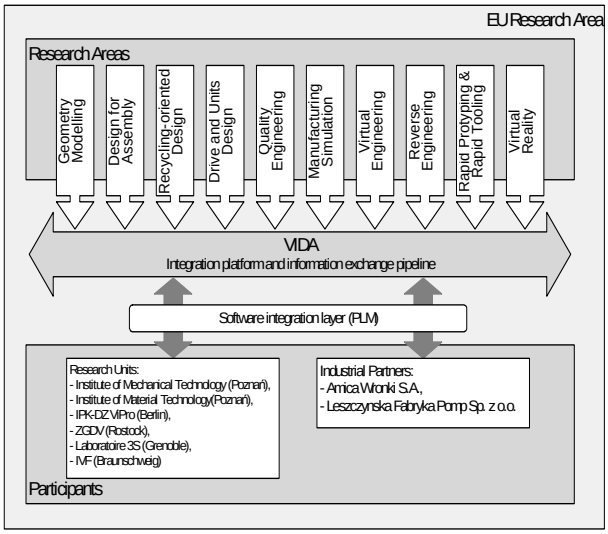

Figure 3: VIDA collaboration platform for integrated design

5 EXAMPLES OF THE INTEGRATED DESIGN AT VIDA CENTRE

The “Virtual refrigerator” project which was conducted at VIDA Centre will be presented as a first example. It was a prototype project for putting the new virtual reality (VR) technology into design process practice. The aim of the project was to create the model for possible product presentation within the factory showroom. A very important element of the VIDA Centre activities is cooperation with industrial partners. The model created for VR presentation was the model of refrigerator manufactured by the Amica Wronki S.A. company, the leading polish household product supplier. This cooperation allows carrying out the tests with the regular product. The great advantage was the accessibility of 3D product model worked out in PTC ProEngineer system with the complete geometrical information. After consultation with the industrial partner, the model was supplied with interactive controlled functionality: opening and closing of refrigerator and freezer doors, opening and closing of the refrigerator multiboxes, modification of the casing version, operating the multifunction electronic control panel. In order to create all the declared functions in the virtual model, it was necessary to use scripting programming. All the work carried out in this project was based on CAD geometry created in the ProEngineer CAD system.

Work on the project proceeded in two stages and began even before the VIDA Centre was equipped with the stereoscopy projection system. In the first stage, a VRML model of the refrigerator was created and then, after the equipping of the laboratory, the EON Studio system was used to create a model for EON ICatcher that drives 3D large format stereoscopy visualization.

There is the significant similarity between the sequence of model programming in the VRML language and the method implemented in EON. The development of model functions is also based on defining the nodes, the prototypes and the routes. However, the EON software

introduces the graphical user interface to the model development process and allows users of all levels of experience to build quickly and easily the complex interactive virtual applications. An interesting solution implemented in the EON system is the simulation tree, which is similar to the model structure tree in CAD software and which shows the hierarchy and boundaries of programmed model interactions that occur as a response to the individual programmed events. It is especially essential when working with complex models.

The project was based on PDM system to check the collaborative design possibility [1]. The goal of the project was to create model of a refrigerator in immersive virtual reality environment. For this purpose a project team was established, where a number of designers from area of CAD and virtual reality, equipped with appropriate computer tools, were involved. The project consists of three general stages: definition of requirements, data conversion and finally, creation of virtual environment (Fig. 4).

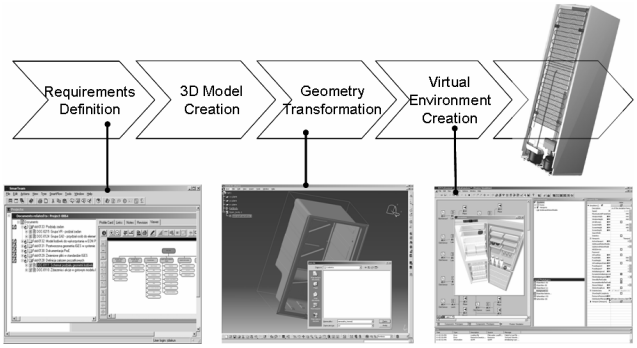

Figure 4: General stages of the virtual refrigerator project

Two groups of designers were appointed to project team: CAD group and VR group. In each group particular participants played different roles – in every group there was a person (group supervisor) whose duty was to verify the results another group members' work. In the whole project there was also one general project manager, who defined detailed project stages, time constraints and input and output data on every project stage. Based on these data the project was implemented in PDM. The pilot project will be used for development of VIDA members cooperation.

Design teams and their members working on the common projects are equipped with hardware (mainly computer workstations), and software, according to their competences and role in the project. The participation in the common virtual design environment is ensured by the PLM client being present on each workstation.

Another example of project conducted at VIDA design environment was water pump design. At the beginning, the 3D CAD model of the pump has been created in Catia V5 system. This model was transferred to FOD (Functional Oriented Design) system, where pump's functions were modelled and costs of the variants were estimated. The variant that fulfilled customer's requirements was transferred into Catia in order to geometrical modifications and generating of technical documentation. Then CNC programs for selected parts of the product were also created in Catia environment. Four poured parts moulds were designed together with simulation of metal flow during casting and cooling, which contributed to optimization of shape and dimensions of the mould.

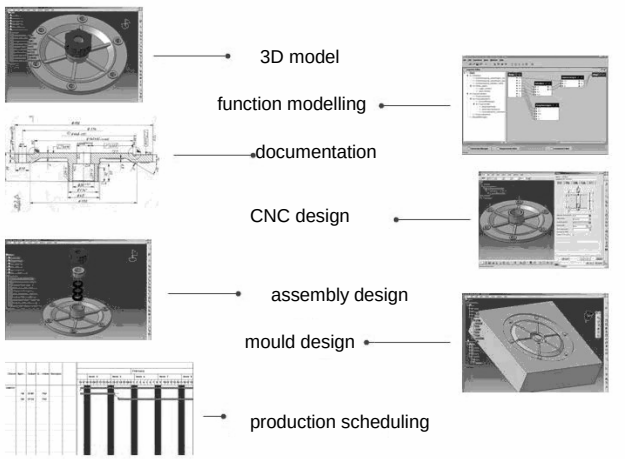

Figure 5: General stages of the water pump project

6 SUMMARY

To manage integrated design activities the collaboration platform based on PDM system is crucial. The use of a collaboration platform changes the character of communication between team members. The communication without PDM implementation is based mainly on spontaneous data and information exchange. Thanks to the internal system mechanism of PDM, the elimination of several minor tools is possible (this mainly applies to popular Intranet and Internet service clients). The implementation of PDM changes the method of organising IT infrastructure. Individual workstations become the location for data processing while data storage is handled

As presented in refrigerator project example, which was developed using the PDM system in connection with VR applications, the use of collaborative platform allowed for coordination of the different VIDA research groups work.

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