DIGITAL PRODUCT PROCESS FOR CONSTRUCTION PRODUCT INDUSTRY

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ABSTRACT: A large research program of digital product process has been active (2008-2012) in Finland. The goal of the program has been to increase customer orientation and productivity in company networks that design and deliver products, systems and services to global markets. For small and medium sized companies the developing of multitechnical products usually has to be done in a network of companies. This requires a lot of data transfer and integration between various computer systems. To improve these processes the research project "Developing the digital product process of multitechnical products to improve the designing and manufacturing of small series product" (Monidigi) has been started.

The aim of the Monidigi research was to improve the design process by using solely digital product information that is handled by proper product lifecycle management systems. The product development is guided by the philosophy of the digital prototype that is tested in a virtual working environment. Products are modeled in 3D and developed by various simulations and analyses before real prototypes are made. This allows a flexible design process and coordinated change management. Digital product processes allow easy data transfer, collaborated engineering and modern manufacturing in a network of companies. Several examples and development possibilities and the state of the art in construction industry are introduced and evaluated.

Keywords: *Digital Product Process, BIM, PLM*

1. INTRODUCTION

1.1 Background

Digital product process (DPP) research program was launched in 2008 by the Finnish Funding Agency for Technology and Innovation (Tekes). DPP consist totally 16 research projects, one of those is "Developing the digital product process of multitechnical products to improve the designing and manufacturing of small and medium series products" (Monidigi), and several enterprise projects. Program total volume is 100 million euros and approximately 40 million euros comes from Tekes. [1]

Digital product process has become an interesting topic because of the increase of digital design data, complex multitechnical products and variety of simulation programs. Each part of lifecycle and iteration of design produces new design data. Therefore processes are discussed from the beginning to the end. The marketing research and requirements engineering phases produce the fundamental product data, which is a precondition for a profitable and cost effective product development. Respectively the product development produces more detailed design data focusing in each iteration cycle of design. In practice it has been shown that in simulation based product development

the amount of data is increased substantially and therefore the benefits of a PLM system are even more obvious.

Fig. 1. Principle of product life cycle management.

Multitechnical product design and the use of several simulation programs require special skills. At present that kind of skills are often necessary to buy from subcontractor as the small and medium sized enterprises usually have limited resources and a lack of competence to fully utilize the modern software tools and systems.

One solution for the problem of growth data is proper product life cycle management (PLM) system. A PLM system gives opportunities to manage, storage and distribute digital product data. It gives also variable tools for example requirements engineering and sourcing. Advanced use and management of digital product data shorten time-to-market, give tools for product information distribution and change management, better and reliable tools for customer requirements and improvements to productivity and economic efficiency. According to company inquiries these advantages are desired in both construction and mechanical engineering industries.

Well managed digital product data is an enabler for more cost efficient and sustainable manufacturing and production. The companies using a PLM system have a better readiness to software tools to optimize production system to match the dynamic market demands and to evaluate the environmental impacts of manufacturing. The previous studies have shown that simulation based design of production systems is an applicable tool [2, 3], but it evidently requires extensive product and simulation data management.

In the after sales digital product data rationalizes planning of maintenance and repairs leading to a longer service life and smaller overall emissions. In the last phase comprehensive product data and operation history enable safe disposal and more sustainable recycling including efficient reuse of components and materials.

1.2 Objectives

The main aim of the Monidigi-project was to create and improve the design process by using digital product information that is managed in a proper PLM system. The secondary aim was to investigate compatibility and integration of various simulation and modeling software's to the DPP and PLM systems. As the field of DPP is very wide the research was concretized with two multitechnical product development cases: a charging vehicle used in underground mining and a rescue and firefighting vehicle. These pilots were multitechnological products directed to construction industry and civil engineering. Also the compatibility of the research results mentioned above was intended to assess and analyze for construction engineering purposes.

2. RESEACH METHODS

In the beginning of Monidigi project a small state-of-art survey was done in Finland, Germany and South Korea. The inquired companies were carefully selected from different branches: designers and manufacturers in mechanical, electrical, software and construction

engineering. Therefore we believe that the survey results represent well the state-of-art of DPP in small and medium sized companies. In Finland a small state-of-art survey of DPP research was done also in facility management industry. The State-of-art surveys are compared and presented here, some conclusions are made and future possibilities are introduced. Surveys are also compared to results of annual CAE/PLM-research which is made by Finnish CAD/CAM-association. Research results are analyzed and main parts are represented.

In Monidigi-research project the design data was managed in a PLM system. Project researchers and designers had an access to the PLM system to save, improve and manage product data and related objects from their own desktops. Brief review to potentiality of PLM system is introduced.

2.1 Product Lifecycle Management

In the DPP a PLM system has a very essential role and there are many different software providers offering PLM solutions. These IT-systems help to manage the product data and to handle the processes throughout the product lifecycle. At the beginning of the Monidigi -project a PLM market research was accomplished to get a picture of the available PLM systems and their properties. After an extensive decision process, Dessault Systémes ENOVIA V6 has been purchased with a various packages of different extension modules. The PLM software supports many different areas of the DPP that are roughly shown in figure 2.

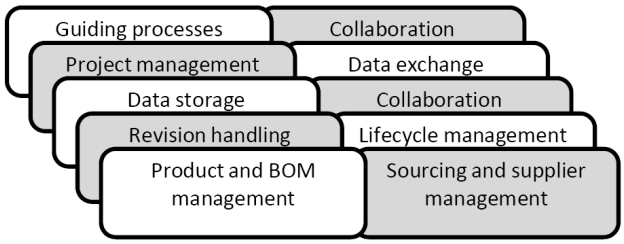

Fig. 2. Different areas managed by the PLM software.

For the Monidigi -project itself the PLM solution's project management tools have been used including the work breakdown structure (WBS) and task assigning functionalities. The latter are very useful in fragmented working environments especially if there are many participants. For concurrent engineering cases PLM solutions offer possibilities of co-working for example in separated workspaces. In these cases members of different companies can work together in a familiar folder-based environment, the workspace. This technique does not require time-wasting trainings for occasional users and furthermore denies them access to the basic PLM-environment. Still the data in the workspace is at the same time inside the PLM system and can be processed within the host company. Anytime data is modified it will be updated in every location it is used or referred to.

PLM solution data is handled as objects (in this paper the term 'object' is used, but different PLM-providers use different terms) that have metadata in form of attributes. Metadata is information about the data itself, for example a CAD Model is the data and its originator or date of creation is its metadata. [4] Besides objects of product data there are objects of processes, for example Engineering Changes. All these objects have their own lifecycle that determines who is allowed to see or edit the data, who is supposed to review it, what has to be done before something can be released to production and so on. Processes within the PLM system are guided by those lifecycles.

PLM systems act as a central database for all kind of product and process data. It is possible to create user accounts not only for members of the host company but also for employees of other companies. Together with

detailed access settings the PLM solution acts as a platform for secure and up-to-date information and data transfer.

Additionally to the properties already described, PLM systems are expanding all the time and offer more and more functionality that is traditionally hosted by different systems. For example supplier and sourcing processes that are usually included in ERP systems, are already included in PLM solutions - project or quality management as well.

PLM solutions are powerful systems not only to handle data, but also processes, business issues and collaboration. Choosing and implementing a PLM system is a very complex project that requires time and therefore money to look deep enough into the subject. It's not only the implementation of an IT-system, since it concerns the whole business processes of a company. Therefore it is required that the uppermost management provides support for the PLM project. [4]

3. RESULTS

3.1 DPP in the mechanical engineering SMEs

According to the surveys of Monidigi project and annual CAE/PLM –research [5] SMEs are generally well prepared for the DPP. 3D - CAD and CAM software's are very commonly used mainly because of integrated usability. For example machining paths can be planned and generated digitally on the basis of 3D models and further transmitted to the CNC based milling machine without manual programming. On the other hand surveys also revealed that corresponding fluent workflow is lacking from assembly processes such as welding.

The integrated use of CAD and finite element analysis (FEA) software's are also very common. This is quite expected result since the utilization of CAD -models in FEA software's is straightforward and widely known practice. However, the reliability of FEA results depends on boundary conditions and initial values which should be adjusted to match the expected physical condition of the analyzed system e.g. external loading or motion of parts.

According to the surveys multi body system (MBS) simulation, like presented in figure 3, is very little utilized in the SMEs at the moment although the possibilities of MBS simulation are quite well known. Some companies had already purchased MBS simulation services. The high price of software licenses and a lack of simulation expertise were mentioned as the most important factors hindering the adoption of MBS simulation in the SMEs.

The multitechnical design cases of the Monidigi project showed that a virtual product model based on MBS simulation cost effectively promotes the development of a product concept and detailed design phase. The MBS simulation offers better understanding of the performance of the whole product consisting mechanical, electrical and hydraulic subsystems. Thus MBS simulation can be used to define more realistic initial values for FEA and to specify control system components before manufacturing of the first real prototype.

3.2 DPP in the construction engineering

DPP in Finnish construction industry have several similarities compared to mechanical engineering industry. 3D – CAD/CAM are widely used in both industries. For example different kinds of column drilling and sawing lines are CAM controlled. FEA are also commonly used in construction structures to calculate behavior of structures in different loading conditions. Simulations as it is used in mechanical engineering industry are used in construction industry quite rarely but in construction planning simulations are used to scheduling purposes. Simulation tools are practical way to present scheduling to large group of people. Short benchmark of Monidigi surveys is

presented in table 1.

Table 1. Industry benchmark based on Monidigi surveys.

	machine engineering	**construction engineering**
CAD	widely used	widely used
CAM	less used	less used (also machine control)
data distribute	email, PDM	email and project bank (server)
data management	mainly windows folder	windows folder, project bank
industry enthusiasm	strong interest	growing interest

In construction industry different design models are collected and combined to a one combination model. With this combination model different parts of design (structures, electrical, heat, water and air) are compared together to find collisions. This process phase gives a possibility to find some errors from the models before construction phase. These kinds of errors are possible because building design employs several designers to work at the same time.

Machine Guidance systems are commonly used in construction industry to increase the utilization of design data. With help of these guidance systems realization data collection has been improved. With help of this realization data we can compare design and realization models of constructed structure.

In construction project building costs are important part of building and therefore DPP in construction engineering mainly focuses in design and building phases. Digital design data that is connected to a PLM system consists project concepts, drawings, quality management, cost management, lean construction and collaboration and some exact BOMs (bill of materials). Concerning to project lead change management is also valuable data. Any BIM (building information model) haven't integrated to PLM systems because in construction engineering lack of standards that describes different elements of a house. Although any BIM hasn't integrated to a PLM system some results from BIM model has been linked to a PLM system from another program.

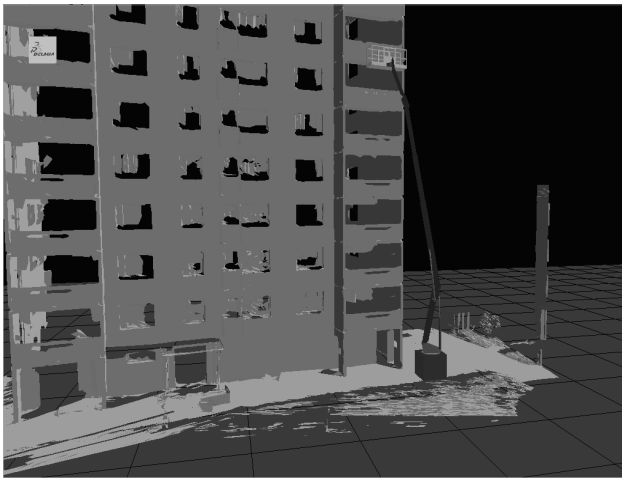

Fig. 3. PLM based modeling – interaction between the building and the machine.

In the Monidigi project a new concept of life cycle was created to purposes for small and medium sized companies. The concept was a mix of well-known concepts of machine [6], simulation [7] and safety engineering [8], [9]. The concept was created concerning to small and medium sized companies is such way that they could easily adopt parts of the concept to their own purposes. The concept was tested with development cases and the purpose was to research how it works in construction engineering.

4. CONCLUSIONS

It can be concluded that the utilization of digital design data in mechanical and construction engineering is in the same phase considering product design and manufacturing. 3D CAD/CAM/FEA/BIM software's are commonly utilized, data management systems are equally developed and collaboration is used often with emails. After

manufacturing differences begin to occur. In construction industry facility management is one long phase in a building's life cycle and the need of centralized data management system has been discovered. The main challenge in facility management is the huge masses of facilities to manage effectively. One special feature of these facilities is that they are old and there is no digital design data available.

The 3D design can be considered as a prequisition for the wider exploitation of DPP. Design in 3D not only supports more efficient manufacturing but also more qualified product development. On the other hand the next level of DPP demands for more integrated use of simulation software's already in the early stage of the product development. Because simulation based development has been found to increase product data substantially it will set a greater challenge for product data management.

In the Finnish construction industry very few companies have taken PLM systems to use. The reason why this is practice is probably that people do not really know what are the benefits of a proper PLM system. On the other hand in construction industry PLM systems are more like project management systems. Used features like project, document, cost and coal management talks behalf of PLM systems in use of projects design and building phase. One interesting area of digital product data is facility management and old facilities. These old facilities are the main buildings that need maintenance most. There are still few problems, like the number of different maintenance systems and the lack of digital data. Facility managers in Finland are interested about the benefits of PLM systems and how a PLM system is suited to their processes.

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