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SOME EXPERIENCES IN IMPROVING DESIGN PROCEDURES

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1. Introduction

Today we notice changes in the world market which dramatically influence industrial companies. The traditional understanding of how the companies view their product and the product's role in the company business is currently being reworked.
Quick design cycle, pressure to save time and reduce costs gets passed from the top of the produce line pyramid down to the small enterprises confronted with tough rules in order to survive on the market. The rules often dictate buying expensive technology. Technology tools used in today's design office save design time, cut the costs enabling designers to visualize their designs in three dimensions, analyze the behaviour and responds to exploitation loads. But small companies often lack the benefits of the technology particularly those arising from system integration and PLM technology. Relatively small companies represented in this survey do not want to invest tens of thousands of euros in new technology.
In this article empirical experience gained through practical projects that aimed to improve utilization of CAD technology in small and medium sized enterprises will be brought out.
Table 1 gives data about number of employees in the design office and the company in total of the four companies which have been involved in the design process improvement recently.

Table 1. General company characteristics

Company	1	2	3	4
Number of employees	50	~350	~350	~1400
Product type	Fire-fighting vehicles: - Adaptive design - Tailored to requirements	Power transformers: - Variant design	Electrical motors: - Variant design - Mass production	Power transmission line towers: - Adaptive design
Number of employees in design office	3	30	20	15

General approach used in attempt to improve design procedures in the design offices can be described with following steps:

1. Data gathering,
2. Recognition of needs,
3. Problem formulation,
4. Solution recommendations and
5. Implementation.

The quality of a particular project heavily depends on the data colleted in this project phase since it is in a way a learning process for the project team whose members are not necessarily familiar with the product under method concern. The project team must gain knowledge about product line(s), design procedures, workflows but also the general product company product development practice and policy.
Besides companies official documentation regarding products developed and procedures used data are gathered through series of interviews covering different levels of company hierarchy and different task specializations.
Interviews were selected as a research method mainly because the data could be collected relatively quickly for a number of design projects. The interviews were semi-structured (Frankfort-Nachmias and Nachmias, 1996), as a mixture of open-ended questions for gathering information about company and of more structured questions used for acquiring information about product and the design process. Although interviews are retrospective in nature they are useful for capturing data in more than one case. Many forms of interview exist and they are generally classed according to the amount of freedom given to the interviewee.
Open-ended interviews simply provide the interviewee with topics and the subject is able to direct the interview within these topics and acts as an informant. Semi-structured interviews ask specific questions, but give the subject room to expand on the answers. Semi-structured interviews allow flexibility in the questioning process and the interviewer can clarify questions thus probing for additional information (Frankfort-Nachmias and Nachmias, 1996). Survey type interviews are the most controlled with only specific questions being asked and are similar to questionnaires.
Interviews were conducted at the company sites and lasted between 30 and 60 minutes per interview.
Extracted information could be structured into different manners. One regarding the products' being designed and produced and the other containing the employee’s personal observations regarding their role and the design process in whole (Suwa, M, Purcell, T and Gero, J (1998)). Another approach is a pragmatic one isolating problems that are in short run critical to firm’s business and if solved will demonstrate benefits allowing more complex problems usually related to the methods used in design process to be dealt with appropriate approach.
Potential improvements can be systematized in three areas:

- System Management
- Training and knowledge management
- Tailoring the CAD system

2. System Management

The migration from dedicated CAD/CAM systems towards desktop systems simplified management issues of current CAD/CAM systems. Much of the day-to-day systems administration can be enacted by well-established procedures, many of which can be scripted, thus minimizing the need for specialist personnel. Therefore more often then not the management and administration of a CAD/CAM system is handled by design office staff who do not have a background in computer systems. However in the small companies the design office lacks the benefits of experienced staff, which have understanding beyond the basic routine of the operating system needed for every day use. Therefore the development of company procedures and systems support for the users within design office is not supported in an appropriate manner. Installations comprising of a several systems, and a network and communications with a server, usually require computer literate staff able to operate the systems. The engineering data which are to be created on the system are a valuable asset to the company and must be properly managed. In particular, careful consideration must be given to the aspects of security and integrity.
CAD applications and especially applications for product analysis require certain minimal computer configurations to be met in order to application to work properly.
Hardware, namely computers, was analyzed using the available software. This was significant for the estimation of the level of CAD application usability which was calculated by the data provided by the application manufacturer suggested as the minimal necessary for application to work properly, and by the actual computer configuration used for application everyday usage.

The health of company's network depends on the quality of network infrastructure - maintaining a reliable network infrastructure is essential in protecting business-critical applications. Also network throughput or "quality" is considering very important for consideration of PDM application implementation.
Evaluation of software was done according to company's particular product and design process. Software evaluation was seen from two perspectives. First perspective was from creation of 3D computer product model and the second was from design process support point of view.
From the analysis suggestions were made in order to company computer and network support to suit their current requirements imposed by design process and product development and manufacturing. Detailed diagrams were created for every company department describing computers, network connections and other necessary hardware. Reports were created proposing actions that have to be taken to increase network and computer levels of security. Likewise the protocols for standard library creation and maintenance and protocols for finished works archiving and backup need to be introduced.

3. Training and knowledge management

CAD model could be linked through rules for/to certain features determining the relationships between design parameters and constraints. More over engineers do not have to start from scratch with each design. They can check previous designs and can determine, based on the archived information, where to best situate engine parts. Rules can incorporate previous experience. Such capabilities are prerequisite since new designs are needed so quickly that engineers can not start from scratch.
Above given statements could be considered as a common knowledge about effective CAD system utilization. However it is easier to be said then done. Many companies do not understand how to map customer specifications to design parameters within CAD environment they use. The problem is how to create a CAD file in which parameters like layout, size, value, material, standard components are related and in which a change of one parameter ripples to affect others.
Proper training for the staff is essential if all the benefits of CAD/CAM are to be gained. To exploit its full potential, the system users need to understand its capabilities as well as be able to drive it. More often then not product designers and manufacturing engineers do not posses adequate level of understanding of the abstraction of FBD (Feature Based Design) models and their usage in creation of computer based product representations is not appropriate. Majority of the engineers in the visited companies have the very basic level of knowledge regarding the general usage of computers. Being overwhelmed with everyday tasks, there is no time left for acquiring knowledge, techniques and skills. It is a common practice that most of the designer have only a basic training, a few continued by advanced training and mostly the special features appropriate to their work have not been considered during education. The companies educational program should also include 'awareness training' for managers and other staff who are indirectly affected by the system. CAD/CAM has far-reaching consequences for the company, therefore it is crucial that all staff are kept informed, especially those who are not directly involved with the system. As a result of such situation although there is awareness that n order to improve prospects company has to embrace new computer technologies but they lack the adequate knowledge to choose the right one. More then seldom costs for implementation new technologies or even for improving existing ones are to high and founding, as always, is directed somewhere else.
Managers at the lover levels are well aware of the problems in the design process but they are to busy in meeting deadlines that they have no time to seriously consider different problem solutions. Senior designers, in most cases, have serious issues about acceptance of new technologies and the novice designers are eager to accept and try new approaches but they lack the necessary knowledge about product and design processes. Also, only 30% of interviewed novice designers were aware of what they needed to know. These findings suggested that novice designers require support in identifying what they need to know (Ahmed and Wallace, 2004). One of the problems was the amount of time designers spent to identify where the required information is in the first place (Marsh, 1997) what inevitably results in need for PDM (Product Data Management) or even product knowledge management application integration in design process.

4. Tailoring the CAD system

CAD/CAM systems provide a standard 'toolkit' for design and engineering offices, and these are sufficient to perform all the basic tasks. However, since all companies have different procedures and standards, the system becomes more efficient if it is further tailored to the specific needs of the organization. The main problem with the software is in its diversity. One of the main tasks of the appropriate company CAE management is the standardization and integration of the software components throughout the company. In that way the necessary data flow and exchange between design teams in different departments could be effectively supported and maintained. However, none of the different CAD packages used can establish full data interchange among themselves thus inevitably leading to unnecessary and harmful product information loss. As an example, features are almost always lost in this way of translation. Such diversity of software can be justified by the need to catch up with global competition, and sometimes by the employee’s lack of will to learn how to operate the new software.

Also, to enhance productivity the existence of PDM (Product Data Management) and PLM (Product Lifecycle Management) solutions was introduced to managements. Therefore, creation of center for exchange and learning of new technologies, knowledge and sharing experience was considered.

CAD systems provide versatile commands to allow different standards to be met for tasks such as dimensioning. The setting of system parameters enables the command defaults to be set to meet the company's own standards. In addition, standard company forms should be established for the users as pro-forma for their work.

4.1 Library components

Many applications require a library of components comprising industry standard items supplemented by company-specific parts. The provision of effective component libraries, and frequently used features of components, is essential to save continual re-creation of the same data and ensure that the system is used effectively. The tailoring of the system to automate a particular process or company procedure with a singe command usually requires special software developed accordingly the user needs and requirements.

5. Case studies

5.1 Fire-fighting vehicle's tank parameterization

This project task was made for a company that designs, develops, manufactures, maintains, services, repairs and sells superstructures for special fire-fighting vehicles and equipment. Analysis of the previous projects and customer requirements that products vaerity depends on additional equipment mounted on the vehicle and the tank capacity that varies in dimensions and water/foam volume ratio. There are four main attributes showed in the table 2. which are important for size and appearance of the tank, figure 1.

Figure 1. Fire-fighting vehicle

Table 2. Tank main attributes

TANK			
Volume		Pump type	Gun location
Water	Foam		

Project was divided into three phase:

1. Problem analysis according to the existing technical documentation of the tanks, creating 3D CAD parts, subassemblies, assembly and drawings in ProE Wildfire.
2. Tanks comparation, parts categorization (standard parts, dimensional variable parts, similar parts with some different features, parts that appear in some cases, parts that appear only once), creating family table of the parts and subassemblies.
3. Tank parameterization. According to previous phases we got 50 parameters which describe the tank. Most of the parameters concern parts dimensions, some of them parts location and the rest of the parameters concern parts resuming/suppressing.

Figure 2. shows ProE-Wildfire interface with parameterized tank model and parameters in the Menu Manager dialog frame.

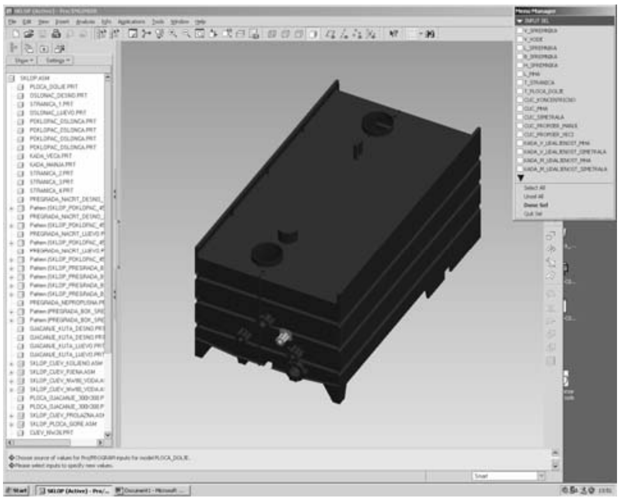

Figure 2. Parameterized tank model

Changing basic design parameters, application generate different tanks with different characteristics and sizes.

5.2 Power transformer's core design

Project that was conducted in cooperation with power transformers producer describes an application created for the embodiment design of the power transformer core as the application subtask that will cover design of the whole transformer.

In traditional transformer development concept the embodiment design and manufacturing phases follow in sequential order. In order to shorten the total product development time, most of the phases are running concurrently, with significant overlaps. The most critical situation arises from the fact that embodiment design phase starts before the project details are fully elaborated with the final contract specification. This was the main argument to build an application that will help the designer to handle not only simple but even rapid changes in the product design.

The needs and specifics of the company's traditional design process were established by a series of exhaustive interviews performed with the senior and novice designers. After the analysis, the system structure was proposed, Figure 3.

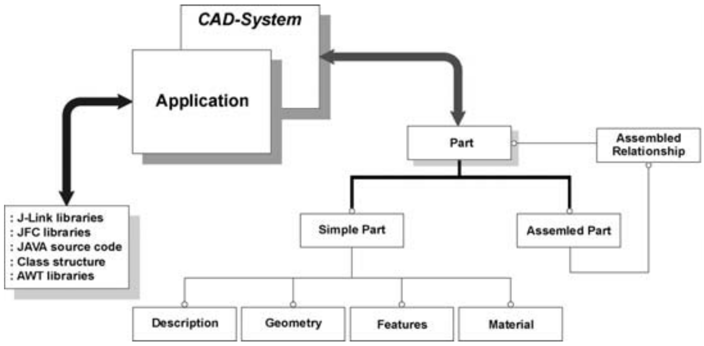

Figure 3. Proposed system structure

Based on this structure the parametric 3D CAD model of power transformer core was created with extensive use of Family parts and interchangeable subassemblies, Figure 4.

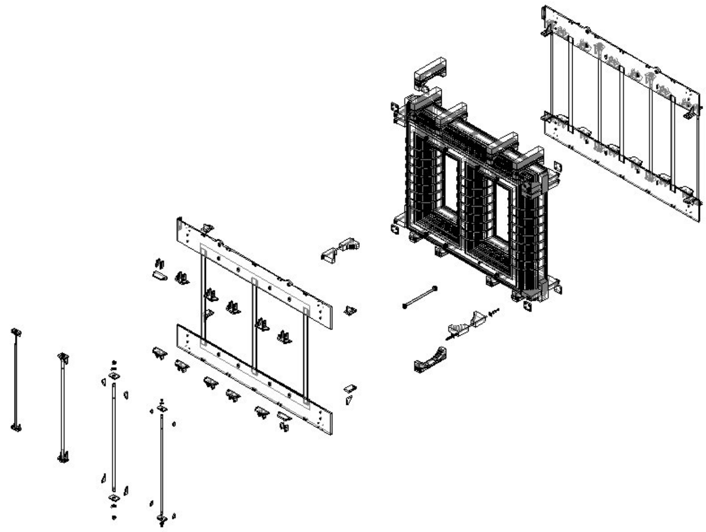

Figure 4. Exploded view of power transformer core (both horizontal and vertical bolt tying)

The project implementation in the real environment has demonstrated dramatic improvements. At the very beginning of system usage core development time has been shortened by almost 60% and the model correctness or the model integrity was improved considerably.

After five months of system exploitation conceptual model was proven to be suitable for the task given. Time spent in design and detailing of the model of power transformer core was considerably shortened and accuracy of the model increased.

5.3 Electrical motor variant design

The subject of this project was the company that designs and manufactures electrical generators and motors in particularly division for design and manufacture of electrical motors (Figure 5.). Due to increase of orders the design department was under tremendous pressure to finish designs and to create documentation for product manufacturing. Also the company was trying to embrace customer individual customization for each product. So the number of product variants quickly increased resulting in more problems for design department. New problems were evident in increase of amount of data and information designer has to consider during product design. This situation was not acceptable and the solution has to be found.

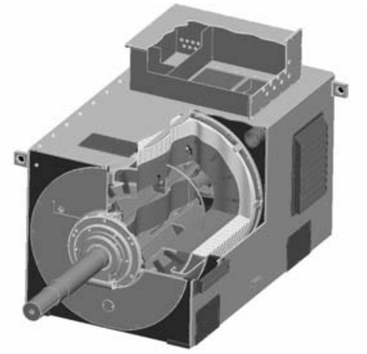

Figure 5. Example of the 3D model of the electrical motor

Our approach was to solve the problems step by step so the company business wouldn't suffer and that solutions could be seamlessly integrated in design process. First, critical and not critical problems were recognized and analyzed. Then problem's solutions and the sequence of necessary actions were proposed. After reviewing order's descriptions the basic set of product variants were recognized and defined. Then each variant was described in detail and taxonomy of variant parts was created. During analysis of variants special attention was put on recognition of interchangeable parts. This was important because interchangeable parts are considered a basis for definition and latter creation of modules and product platform. Secondly, the variant 3D models and technical drawings were created. For every 3D model an interface was created in order to enable easy and quick product variant creation and control. Company designers were involved during each of the steps so they could learn, on the fly, how the model was created and how to use efficiently. For the test purposes variant models of the stator and coil were created using Pro/Layout module as the part of the Pro/ENGINEER application.

5.4 Power transmission line towers

Project was developed for company that design and produce transmission lines and substations with auxiliary equipment and other similar products.

Results that came from interviews conducted with the company managers and employees emphasized that there exists a need for better utilization of engineer's work hours. It was clearly shown that the daily activities of an engineer are structured as a mixture of many often disturbing tasks (i.e. attending meetings, writing reports, doing endless e-mail corresponding etc.) that are in the end not at all or little connected with their prime vocation – engineering. There might be a justification for that in a view of today's global market which imposes such non-engineering demands on the engineers.

The main difference between the computer and a human being from which can be devised the reason for a proper computer usage, it's in a machines ability to very fast perform thousands of repetitive operations with none what so ever human intervention. In order to save time and alleviate the workload on the engineers so that they can turn their focus to real engineering problems, the significance of automation of any repetitive task (in the design process) clearly gains on significance. CAD package encountered in the company was Dassault Systems CATIA V5R14 and the need was shown to produce an automation script consisting of two major parts:

- First to program a script for automatic propagation and definition of the user properties between components on the user chosen assembly/subassembly level, and
- To devise a script for automatic transfer of these user properties into drawings, and in that way produce an fully automated assembly drawing constructor with a corresponding bill of material creator and a full two way association. In this way the properties of individual assemblies could be accessed through drawing documents.

That was a reasonable request because the manual definition and later management or changing of the user assembly properties can be a daunting task especially if the assembly itself consists hundreds of parts. Same situation is encountered with later definition of drawings which need to be up-to-date with their corresponding assemblies, and must provide an easy way for managing assembly properties. Both scripts were programmed in Microsoft VBA and successfully implemented. Future work will include the development of more complicated automation scripts or software like CAM scripts, robot path calculators, ISO tolerance table constructors etc.

6. Conclusion

Created variant models significantly shortened the design time allowing firms to quickly respond to design changes thus enhancing the overall production process. Furthermore it was considered practical to concurrently create variant FBD models of components alongside the development of platforms and modules in order to create a firm basis for creation of product configurator.

The problem that appeared at the initial stages of each project is the level of designers' comprehension of product FBD model. The lack of complexity and abstraction in understanding of FBD models is often present. More so the importance of FBD model in the future, especially in PDM (Product Data Management) and PLM (Product Lifecycle Management) solutions was often misunderstood.

The results aimed in the presented case study have demonstrated that even small investment in three areas, namely system management, training and knowledge management and tailoring the CAD system can bring significant benefits in technology utilization.

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