ELABORATION OF ELECTRONIC SIGNATURE PROCESS: ANALYSIS OF A CASE STUDY

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Abstract. *It is always a great challenge to manage the uncertainty involved in a Product Development Process (PDP) because the decisions that cause major impacts in the process need to be taken at the stage where there is little amount of information about the product which is being developed. The challenge is further increased when the development process is based in a cycle of design-build-test, which generates interactive multidisciplinary activities that might evidentiate strong technical and culture restrictions about the required integration. Aiming at increasing the reliability of the PDP management as well as decreasing the PDP lead-time, this work proposes a process that replaces manual for electronic drawing signatures, thus simplifying the drawing approval process as a whole. This new process guarantees that the approved model is the one to be released to the design teams and keeps track of the drawing modification status during the signature flow. The proposed process is based upon IPD (Integrated Product Development) and product digital manufacturing concepts and procedures. It is implemented through the management tools of virtual development - ENOVIA™vpm - and its applications. The proposed process has been applied in an aircraft manufacturing company and the initial results are rather encouraging.*

Keywords: Electronic Signature, Product Data Management, Integrated Product Development

1. INTRODUCTION

The decisions taken in the initial stage of a project can directly affect factors such as cost, quality and performance of a company's products. One of the known factors about a product development process is the high degree of uncertainty in the beginning of the process, when most of the solutions that will meet the project's requirements are defined. It is a great challenge to manage the uncertainties involved in a product development process, as the decisions of more impact need to be taken when there is a higher number of alternatives and a high degree of uncertainty. Some factors increase the challenge even more, as the fact that this process is based on cycles of projecting-constructing-testing, generating interactive multidisciplinary activities in environments that can have strong cultural and technical barriers to integration.

In the middle of last century, the product development process of was carried out in a sequential way, that is to say, each functional area of the company used to transfer the finished documentation to the following department, after executing its development activities, and so forth. The professionals involved in this traditional development approach were specialists who knew well the technical scope of the products, but they did not have an overall view concerning the development process. This approach was possible when the products did not have great technological sophistication. With the advance of technology and products' growing complexity, this approach became inefficient. Besides, the companies started having several problems and limitations, such as: difficulty in designing with simplicity, lack of attention to the quality of the product, excessive development time, lack of integration between the design and production phases, lack of focus on the customer, little involvement with suppliers in the product development and imperfections in the process of continuous improvement (Clausing, 1994 and Valenti, 1996).

According to Valenti, (1996), a study elaborated by ASME (American Society of Mechanical Engineers) and published by the National Science Foundation, has identified the main approaches, technologies and tools used by companies that were successful in their products development processes. As part of this study, personal abilities needed to be acquired to use these approaches, technologies and tools in a consistent way. A great emphasis has been given to teamwork, communication, creative thought and the use of approaches that would try to establish synergy between several areas of the product development process (Rozenfeld, 1997). These results reflect the current concern about modifying the profile of the people who work in a conventional way, changing this view point to a holistic view.

The authors of this work believe that the Electronic Signature process for engineering drawings also contributes for this necessary change of view. Naturally, this is a secondary - and very important - effect of the considered method, whose main benefits are the simplification of the drawings approval process, the minimization of approval time, the increase of the reliability of information and modifications register during the information flow. The implementation of the proposed method herein presupposes the use of cooperative tools and the execution of teamwork. To do so, Simultaneous Engineering supplies the conceptual bases for accomplishing the proposed method. This is detailed as follows.

2. SIMULTANEOUS ENGINEERING and the PDM (PRODUCT DATA MANAGEMENT) INFORMATION SYSTEMS

In 1982, the DARPA agency (Defense Advanced Research Project Agency) was already concerned about how to increase the degree of parallelism of the products' development activities. The result of this work, published in 1988, defined the term Simultaneous Engineering in the following way: "Simultaneous Engineering is a systematic approach for the integrated and parallel development of a product's project and the related processes, including manufacturing and after-sales phases. This approach tries to make the people involved in the project consider all the costs, deadlines and customers' requirements, since its beginning." (WINNER et al., 1988 apud PRASAD, 1996, p321). This definition implies that it is not enough to have only the traditional Product Engineering mobilized in the implementation of the Simultaneous Engineering concepts. It is necessary to have the involvement and participation of representatives from several areas which can offer knowledge and experience to the product. That is the reason why it is necessary to form coordinated multidisciplinary teams, aiming at a final goal: to satisfy the customers' needs, what will undoubtedly bring financial return to the corporations. The areas of marketing, sales, technical assistance, tests, manufacture, engineering, dispatching and other areas must be at least partially involved.

From the definition above, the concept of Simultaneous Engineering has become much more comprehensive, including the cooperation and the consensus among the people involved in the product development, the use of computational resources such as CAD (Computer Aided Design), CAM (Computer Aided Manufacturing) and CAE (Computer Aided Engineering), PDM (Product Data Management) systems and the use of methods such as DFA (Design for Assembly), DFM (Design for Manufacturing), QFD (Quality Function Deployment), among others. From the literature review, the characteristics about the implementation of Simultaneous Engineering in a company were gathered, as shown in Tab, 1.

Table 1. Literature review of the Simultaneous Engineering (SE) relevant characteristics

Characteristics / Authors	Multidicipli nary Teams	Custom er needs	Early phases investments	Computing Tools (CAD/CAE/ PDM)	Whole lifecycle	Decrease of *Lead-Time*	Culture change
Prasad, 1997	√	√	√		√	√	
Rozenfeld, 1997	√	√	√	√	√	√	√
Junqueira, 1994	√	√			√	√	√
Melhado, 1994	√		√	√	√		√
Tzortzopoulos, 1999		√		√	√	√	
Hartley, 1990	√	√	√		√	√	√
Ellis, 1992				√	√		
Romeiro, 1993	√		√	√			

Some of the SE characteristics brought by Tab.1 are further detailed as follows.

2.1. Multi-functional Teams

With the Simultaneous Engineering approach, the product development process activities have started being executed in a concurrent way, e.g.: the decisions involved in this process considers the requirements and experiences from the several areas involved. As for the professionals, several authors state that the activities related to products development must be carried out by a multi-functional team.

According to Moura (apud AQUINO, 2004), Simultaneous Engineering can be considered a way of company reorganization, replacing the barriers imposed with departmentalization for the concept of multidisciplinary teams, through systematic communication, human resources training, establishment of partnerships, that is, an effective integration of all agents that participate in the product development process. According to Gomes (2005), in the structure of this task, everybody is supposed to know what their functions and jobs are and must be prepared to work together.

The team of professionals, structured in the initial phases of the work, identifies the problems related to their own areas in order to solve them, creating strategies for the improvement of products and processes (Goldstein, 1991). This interactivity, according to Fabrício (2002), is characterized by the availability of the information on the project to all the people involved, co-located in multidisciplinary and inter-departmental teams, so that they can interact in a simultaneous and coordinated way in all aspects of the new product. The author adds that, to do so, it is relevant to form product development teams, whose purpose is to use in the projects the experience from diverse specialties and different functions that compose the productive process in progress, aiming at the establishment of interactive formal communication processes, whose coordination can guarantee the distribution of pertinent information to the participants in the project team.

The success of the teams is directly related to the commitment demonstrated by the administration of the organization, which must show total support for the development of their capacities and make available for the team resources and manners to perform the task. The administration transfers to the team, the responsibility to pursue the project, periodically assessing its performance.

The Simultaneous Engineering strategy for product development involves integration between the departments involved (specialists) and the suppliers. To develop the product in a simultaneous way, the work environment must be appropriate, promoting a strong interaction between the people involved in the development processes, either sharing project data or taking decisions in teams. In order to do so, the companies are investing in information technologies and management tools.

2.2. CAD System roles

Romeiro Filho (2004, p22) emphasizes that the option of using CAD tools, which are "a multidisciplinary technology, a set of tools used by all areas for integrating digital information and the project's activity, as well as the control of this process management ", makes the project development to be conducted in an orderly and correlated way. The author highlights the importance of CAD in the significant reduction of the necessary time for a product development, eliminating and/or reducing certain stages of the project cycle, through more integration between the diverse project and production areas, and even between different companies.

Likewise, Romeiro (1997) affirms that computerization is an important tool for the implementation of Simultaneous Engineering, as long as the methodological approach precedes the process computerization, because the computer science does not bring consistent benefits to the company if the project process is structured in inconsistent and defective platforms.

Regarding the process improvement, in accordance with Tzortzopoulos (1999), the gain in efficiency and effectiveness of the activities that constitute the project process is based on the use of project tools, such as CAD.

Some companies have emphasized only the organizational aspects of Simultaneous Engineering, such as grouping people together in functional departments. Other companies have invested in the integration of CAD/CAE/CAPP systems (Computer Aided Design/Computer Aided Engineering/Computer Aided Process Planning) to share a single product model. During the simulation activities originated from the integration of these tools, people can improve their knowledge about product development, with focus on a holistic view of the entire process.

According to Fabrício (2002), the use of Information Technology, through the computerized integration of the project, provides the opportunity for new technologies and new possibilities of calculations and simulations during the project, extending the products' capacity of technological development. It is also emphasized that, on the other hand, the possibilities of long-distance telecommunications and collaboration on the same project database enable the integration of specialists who are geographically apart and speed up the exchange of information between the agents of the project. This scenario has come through thanks to the internet tools which enable project interaction, and guarantee the same level of information is delivered to the several agents. The development of such collaborative environments involves aspects of several areas, including users' interface, communication infrastructure and systems for shared objects, establishing systems that are essential for the success of simultaneous tasks (BOLLMANN *et al*, 2005). In the context of Information Technology, CAD 3D is a quite consolidated tool in many branches of Engineering, especially in products' simulations.

2.3. The collaborative tool CAD and the Digital Mockup

The CAD systems incorporated with volumetric geometric models, e.g. 3D (three-dimensional), enable the use of DMU - Digital Mockup – that is the virtual model of the product. The DMU application in a simultaneous work environment is an enabling aspect of Virtual Engineering, making it possible for designers involved in the product development to perform simulations close to reality in a computer: then, it is possible to see and verify the product's assembly imperfections, assembly interferences among components, available spaces for cables from devices and ergonomics, among others characteristics. These problems can be clearly identified and corrected by the designers in the development initial stage.

Technological investments are necessary to prepare the necessary infrastructure for the implementation of DMU. Besides, in order to successfully implement Simultaneous Engineering, it is necessary to have effective communication. This communication involves people, data exchange among the systems such as CAD/CAM, and, maybe the multidisciplinary team's most important activity, the documentation and management of the information and the decisions taken, so that they can be used whenever needed.

2.4. Data management tool - PDM

Many companies face problems when implementing an integrated projects environment. This is due to the difficulty of managing the information created and the activities to be accomplished. The product data management systems - PDM – developed in the 90's are used exactly for this purpose. Conceptually, PDM is a software technology that aims at managing all the information as a single database of processes related to a product life cycle, from conception phase to phase out, going through the project and production stages. The PDM technology aims at exploring all possible benefits of simultaneous engineering, controlling the information and systematically distributing it to the people who need it, through controlled accesses, according to previously defined profiles.

For some companies, the usage of PDM technology results in competitiveness improvement, due to the rational use of investments already made in technology, the improvement in operational procedures, the support to information exchange between partners and the fulfillment of the industry required standards.

2.4.1. Management system structure - PDM

There is a great variety of PDM systems available on the market; the difference come in several aspects, such as the application field, the system architecture, the comprehensiveness of functionalities and cost. However, most of them use the same principles to manage information, which are:

- Server: the server is where the managed files are stored. It is the part of the system which guarantees the information security and the users' access control;
- Metadata: it means information about information. This data is information on the files, which allow them to be managed. Some examples of metadata are: file description, owner, part number and creation / modification dates.
- Integration: in order to get the required information about the project, the PDM system needs to be integrated with the applications that generate information.
- Interface: the interface of commercial systems is generally graphic, and allows the user to quickly access the available information.

2.4.2. Management system functionalities - PDM

The basic functions of a PDM system are twofold: product data and process management. The former manages product data including product structure control, components and documents classification; the latter, the design process, including the activities related to work flow, such as product approval and engineering change.

This work focuses on the second functionality of the PDM: an engineering modification executed by the designers is sent to the people responsible for the documentation, who updates the structure of the product in the CAD models and, through electronic documentation, he (she) verifies and releases the reviewed drawings and other documents.

3. E-SIGN PROCESS (ELECTRONIC SIGNATURE)

Despite the great development of information technology, most industries control the engineering information on paper. Many of them still use a manual system to control the information about the product. There are many resultant problems due to this situation, and they directly affect the performance of the products development process, for instance: outdated copies of drawings circulating to the people responsible for the process, and later on, to assembly workers, slow circulation of documents, excess of paper, high rework rate, lack of feedback and difficulty in getting information about the products. Aiming at managing electronic documents and guaranteeing their security, organization and the consistency of the information, since the beginning of a product development cycle, the implementation of the Drawings Electronic Signature process (E-SIGN) is proposed herein, replacing the manual counterpart. Figure 1 shows the phases of the E-SIGN process.

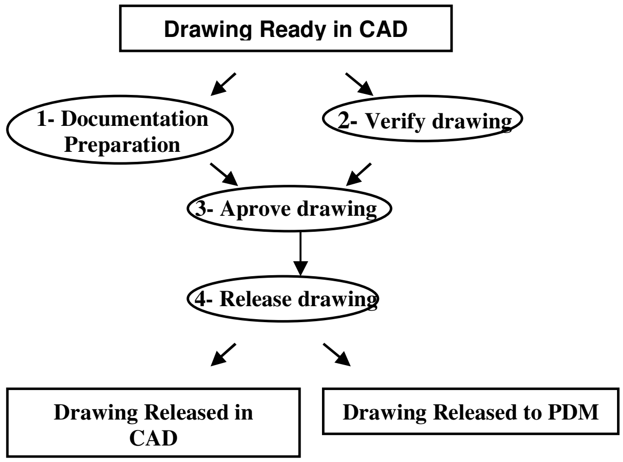

Figure 1. Phase of Releasing Process.

Based on the DMU created by designers using CAD, PDM management system and Simultaneous Engineering, the E-SIGN process allows specialists from other departments to use the information contained in a single database, in real time, for analysis and then, later on, it allows the release of information for the continuity of its life cycle, guaranteeing that what is being signed is the same information that is released to manufacturing and inspection phases. The management of this process includes functionalities related to workflow, such as the approval process of a product and its modifications.

The usage of the workflow support systems is fundamental to manage the flow of information in the process of engineering modifications, in a simultaneous engineering environment. Currently there are several systems that intend to achieve this objective by using different approaches. The workflow system stands out in this function, as it supplies resources for a quick search, for version and status control and for electronic notes (redlines). In this type of system, the documents are shared by several people who are geographically apart, and they pass sequentially from one person to another, enabling higher speed in the information cycle and security in information transference, besides facilitating the communication between people.

With the evolution of local computational networks, the sharing of information resulting from individual work and of existing resources has become available (hardware and software). From then on, the workflow procedures have started having a fundamental hole in the automation of information flow by assuring an efficient distribution of information besides the primary data, such as warnings and actions, among others.(AUSSEMS, 1994).

The interface of a PDM environment must enable the interaction between several users simultaneously. For the user, the interface is not only the access to the system, but also the access to the other people and departments that are part of the multidisciplinary teams involved in the product development process. The PDM interface, when configured for the cooperative environment, must fulfill the following requirements: the applications have to be consistent (the information is frozen in right time) and the system must give the user some feedback, every time an action is performed by the user. In the proposed PDM environment, the following functions stand out:

- Communication: it enables communication and notification between the users, keeping the interface with the e-mail system;
- Data transference functions: enables data exchange between the users of the system, and between different applications;
- View: consists of mechanisms of quick view for images and redlines (electronic notes);
- Administration: guarantees configuration, customization, control of users and system management.

3.1. The E-SIGN Process and Simultaneous Engineering

In E-SIGN process, the concept of Simultaneous Engineering was implemented in an aircraft development company, taking into account especially the characteristics shown in Table 1. By using the workflow method at the moment of signing drawings, the release process could be controlled through registers and status of product’s drawings and possible modifications. With the elimination of unproductive tasks (for instance, the designer transit necessary to get the paper signature, scanning or microfilming drawings and documents), the overall time spent was reduced, increasing the gains with the productivity. With the help of the PDM management tool and the workflow system (Figure 2), it is possible to track the process, identify problems earlier in the design process and avoid rework on later phases of the product lifecycle process.

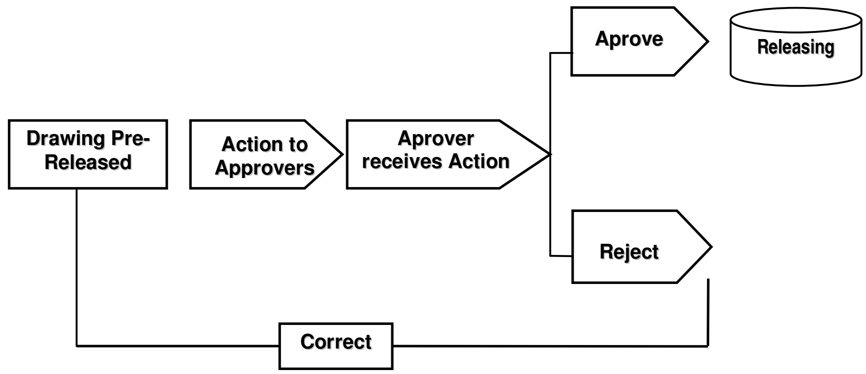

Figure 2. E-SIGN Process.

Following the Designing Product and Process approach, the main characteristics of the product are evaluated, calculated and verified through simulations. In order to do so, DFA and DFM techniques are used, whereas the Digital Mockup (DMU) and the CAD/CAE applications are used to anticipate problems associated to tolerance and manufacturability At the detailing phase of the PDP, an electronic assembly of the final set is elaborated, when the dimensional chain is verified, improving the details' specifications, without preventing this information from being concomitantly used by other people. A principle that orientates the people's work in this phase is the assured quality information, i.e., the information produced in a stage called "advanced" is then released to the team, so that people can continue the work that depends on this information before its approval, that guarantees a parallel work.

In order to assure information integrity, it is controlled by the PDM system. If a piece of information - for example, a drawing - is rejected (and corrections are requested), the processes that depend on this drawing can be easily tracked. Tasks are sent to the other members of the team through the workflow (the Enovia™-VPM was used in this work). This integrated way of work relies on multifunctional team, people self-control and disciplined mentality, and mainly, on a change in the company's culture. With the implementation of the (E-SIGN) process, the following results were obtained:

- elimination of paper excess;
- information consistency;
- elimination of unproductive meetings;
- efficient communication;
- execution of teamwork from different sites;
- strengthening of the synergy between the members of the work teams;
- improvement in the production of documents and projects;
- communication of important actions to team members;
- working with the correct version of the product drawing;
- evaluation of manufacturing processes as soon as possible;
- better management of the structure of the product;
- better use of standardized parts;
- easy and quick access to product data;
- real time follow up of tasks and status, making it possible for managers to make decisions in time to minimize the product life cycle.

Besides, during the process of Electronic Signature, anytime during the details phase, any member of the team can consider an item as being a critical item, when his (her) assembly or manufacturability is detrimental for any reason, either geometrical or of manufacture. This could mean that the component complexity is incompatible with the company capability or with the development of long term demand (long cycle). In these cases, an extra meeting is set for all members of the team, in order to release the critical items faster. They are classified as development constraints and start to receive more attention from the development team.

4. CONCLUSIONS

In this article, an Electronic Signature Process (E-SIGN) using the Simultaneous Engineering resources has been proposed. The major benefit of the E-SIGN process is to track the releasing status of drawings, in real time. The drawings are analyzed for managers during releasing. They can take important decisions during the drawing detailing phase. For example, increase the ma power to reach the previewed time for releasing an item. After release is possible generate visibility with information of all drawings returns and your reasons, average releasing time, among other. This visibility helps in release loading management and reworks can be avoided.

It can be pointed out too, that the usage of a unique database (PDM) to multifunctional team, guaranties that everyone works on the same information, that be related with the last drawing version, bringing in reliability to process.

According to the literature review, an important item for PDD is to reduce the product design lead-time. It is important to remark that the preliminary use of the E-SIGN process has yielded a decrease of 35% in the average releasing time for drawings, from 8 to 5 days.

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