AEC and Concurrent Engineering

by

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Abstract

This paper studies the organization of designers for the development of AEC projects, according to the principles of Concurrent Engineering. Originaly oriented to mechanical and electronic products design, Concurrent Engineering can be successfuly applied to other engineering projects like: industrial plant design, nuclear plant design, naval shipbuilding, chemical and petrochemical plant design. The requirements for a computational environment is listed, by analysing the activities of design engineers at work. A complete computational environment is then proposed, with PDMS as the main computer package. To assure the efectiveness of the proposed system, a small part of a complex project, is developed with different organization approachs. This paper also offers the main directions for organizing people for the design automation change in engineering companies. Finally, it is possible to verify the maturity of engineering design automation technology, and the real potential of the present tools for its implementation.

Introduction

Companies in the 90's are continouslly changing to keep their share of market, and to quickly respond to client's needs, international competition, environment-save policies or to accomodate to technology innovations. Not only products are changing and but also do the companies themselves. Engineering companies around the world cannot be apart, they must be alert for new technologies that can affect their way of doing business.

CAD technology has been responsable for big changes in engineering offices for the last ten years. A lot of successful cases have been reported on various fields of application. Nuclear and Power Industries are among those who are using 2D-CAD in their design process, another fewer number of companies also use 3D models for conceptual design. The main problem in the use of 3D-CAD is that the real benefits of this new tool, came with drastic changes in work organization, that may frightens some companies from implementing it.

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Concurrent Engineering is an approach that integrates product development with other areas of the company. It embodies changes in organization like teamworking, collaboration and extensive use of computer technology. This paper studies the application of Concurrent Engineering principles in AEC projects. A brief review of the technique leads to a list of basic needs for an engineer, when working on a team. These needs can be translated into software requirements for a computational design environment. To verify the dificulties in developing a design with engineers working at the same time on the model, a small portion of a plant with equipment, structural and piping components can be developed, during a benchmark test of PDMS software.

Concurrent Engineering Definition

The term Concurrent Engineering was first used in 1986, by the IDA - Institute for Defense Analysis, on a study to improve american industry competitiveness [Cart 91]. It was defined as:

> *"Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from outset, to consider all elements of the product life cycle from concept through disposal, quality, cost, schedule, and user requirements"*

The traditional product development process follows a sequential path of activities, from marketing and conceptual design to detailling and manufacturing. A project error, or a change, brings the design back to the start of the process. Even if each step is very efficient the whole process is slow and error prone.

With the concurrent approach, a team of different specialists is formed to attack all possibles aspects of the product at the same time. Changes are made and errors are detected in the early stages, where they are inexpensive to be corrected. Communication, with the use of computer graphics, plays an essential role in the success of this organization. Productivity is then obtained by the whole team, not only by one member alone.

Benefits

The main benefits of Concurrent Engineering approach are:

- *Reduction of time to complete the design*. As it has fewer errors there is no need to expend time correcting them. The job gets ready sooner.
- *Higher quality design*, as a result of the reduction of errors, and the use of computer technology, that permits more precision in design and analysis. The exchange of experience among the specialists also results in better products; and
- *Total cost reduction*, comes with the less work being spent in the design and with the better design decisions that a team can make.

Dificulties

Although every company is looking for these benefits, there are some big difficulties in achieving them. They can be divided into two types: technical and human. Techincal hurdles are related to the need of computational tools to allow engineering teamwork and collaboration. The human resistence is a result of a not well understand of the benefits and risks.

The continous evolution of computer software and hardware has permited to create an effective teamwork environment, and to implement the concepts of concurrency into the engineering work. Networks and computer graphics made possible to communicate technical data efficiently, with computers.

The answers to people's resistence are trainning and commitment of upper managment to the changes. Trainning make the designers confortable with the software and its potentials, and give them the feeling of a professional grown. Managers can share the risks with designers by been deeply involved in the process of change, listenig to suggestions and motivating the team.

The Designer needs

The basis of developing a project in a parallel way is to form a multi-discipline team of designers to work in the product together. The members of the team communicate to each other with the aid of a net of workstations creating a so called *virtual team*. A manager organizes the work by assigning responsabilities, and controling the flow of information within the team. A computer infrastructure supplies special services, like plotting, software support, external communication, backup, archiving, and other facilities. Figure 1. shows this environment organization.

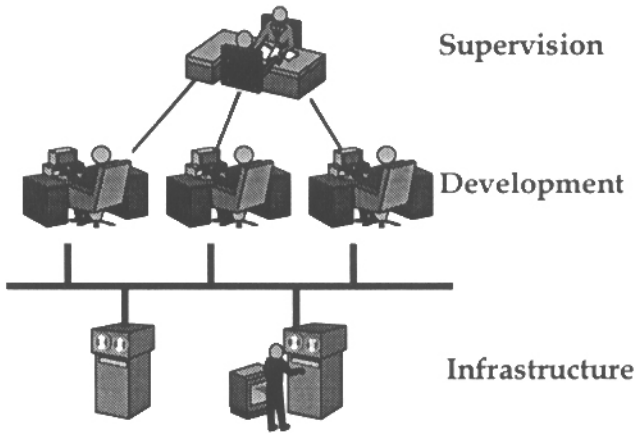

Figure 1. Organization for Concurrent Engineering

Each member uses the workstation to support its own activities. Computers give speed and accurancy to engineering communication and calculation. Each member of this virtual team, as observed by Reddy et alli [Redd93], will do a set of activities, listed bellow and represented in figure 2.

- *Lookup*: where information is scattered throughout the organization, and stored for future use. Document managment software can be helpfull by creating a single point of inquiry (the information server).
- *Compute*: the designer adds value to the information, editing graphics, text, multimedia, etc. All formats of information must co-exist and need to be integrated. CAD software is very usefull at this point.
- *Communicate*: Sharing information, every one in the team must have access and understanding of each others information.
- *Negotiate*: Design decisions must be achieved by consensus. Blackboard technologies and multimedia conferencing are helpfull.
- *Decide*: There is the need of decision making tools to assist the members in group-decision making.

- *Archive*: The knowledge of the organization must be captured to be used in future developments.

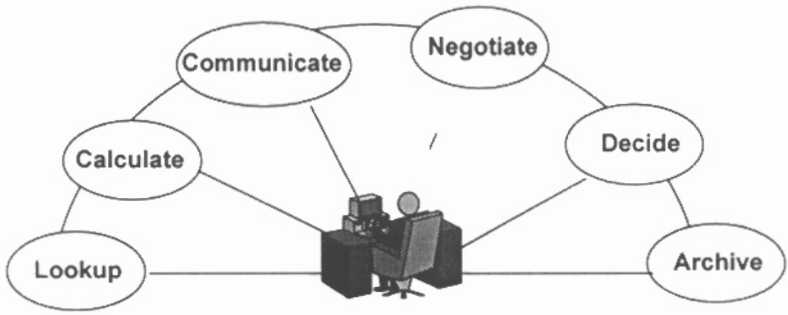

Figure 2. Activities of a Team member

To create a computer environment to support the teamwork, it is needed to select software tools to support each of this activities, and to organize the activities among the members. This organization and software selection is very much depedent of the type of product to be developed.

Concurrent AEC

There has passed more than ten years now, since CAD software started being used in AEC design. The first step on the design automation process was to increase productivity in repeated tasks like drawing and materials take-off. These beneffits do not garantee a complete assimilation of the CAD technique into organizations, and some deceptions may have occured.[Plon89, Majc89].

The application of Concurrent Engineering principles can help the organization to realize the great benefits of CAD and other computer related technologies, by offering new methods for the development of projects.

The first industries to get benefits of Concurrent Engineering where those that have short life-cicle products. It takes at least two life-cicles to complete implementation of this new methodology [Cart91]. Mechanical and Electronic products industries are been sucessful in adopting Concurrent Engineering [Rose91]. Long life-cicle products, like construction industry, take more time to reach these results [Mill91,Rose91]. There are some aditional difficulties in adopting it in AEC :

a) AEC projects are much bigger, in scale, then most mechanical and electronic ones. Not only more designers are need, but it also involves a larger number of disciplines.

b) The mean cost of an industrial plant is normally greatter then the costs of production of other products, what make managers be more conservative with innovations;

Although there are difficulties, AEC projects can be as much rewardable, as mechanical and electronic projetcs, with the application of a parallel organization.

The PDMS software organization

A tipical plant design is done by a large number of specialists, from different technical areas like: process, equipment, electrical, civil, concrete, HVAC, structure and piping. The first part of the design of a plant defines the process, in a schematic P&ID diagram.

The concept design and detailling phase is tradicionally done as a serial process, from one engineer to the other, starting with equipment placement in the layout of a site, then the piping experts connect the equipments, then structure and finally HVAC and electrical trails are located. The sequence may vary from project to project, but there are always a great conflict for spaces in plant design. Interference can be detected, if one has a complete 3D model of the plant, and the appropriate CAD software. PDMS sofware allows each designer to model their components, and they all be checked for colisions. When a problem is identified the design must be modified. PEGS is a PDMS fully integrated P&ID drawing software, and can create an unified environment for the development of AEC projects.

When concurrency is applied in order to improve productivity, the question that arise is how to avoid colisions, no only correct them. The problem becomes how to organize the use of the software, so that the re-work of correcting the model is minimized.

There are basically two ways of integrating the work of the various designers: a serial and a parallel way. In the serial design organization the model is passed to one specialist to another. The sequence of specialists and the structure of the model, depends on the type of plant, and its complexity. In the parallel way the model may be modified by several designers at the same time. Some method of control must be implemented, to discipline the concurrent access and the construction of the model. The requests for each designer to change the model must be managed to keep the project under control.

Some forms of organization of the PDMS software, to control the interaction of designers with the model, are then proposed, trying to accomplish a correct model in the shortest possible time.

Serial Design Development

This is the implementation of the traditional project organization in a 3D CAD system. In this case the model is "transfered" from one designer to the other. The transfer is done by allowing only one designer to access the model at a time. Interference checking can be done from time to time as the components are being placed. A clash or design error, when detected, makes the model return to a previous specialist to be corrected. Negotiation and decision is done by one designer at a time.

Figure 3, bellow, exemplifies a serial organization. After the equipment designer (Des1) finishes its work, for example, the access to the model is transfered to the piping designer (Des2), and finally to the support structure specialist (Des3). The PDMS 3D CAD system allows a simple and effective clash detection at the end of the cicle or interactively during the design section.

This type of organization offers a better control of the process, because one allways know who is responsible for the job. Computers can enhance productivity and communications between designers and the client, who can watch the model evolution.

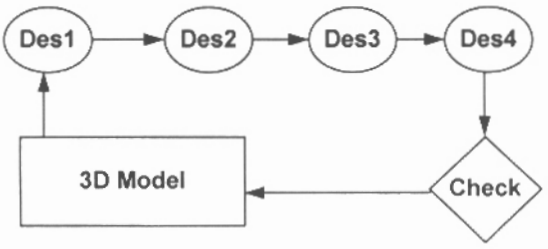

Figure 3.: Serial Design Organization

Parallel Design Development

The use of computers in design allows interaction of various designers to the model concurrently. The idea here is to place the equipment, piping and structure in the same site, at the same time. As the tasks are processed together, they can be completed in a shorter time, and the clashes can be located and solved sooner.

There many ways to implement a parallel design with PDMS, depending on the level of control that managers want to have in the process. It is possible to control the access to the whole model, or control the access to parts of the model database. There are two different approachs for a parallel organization, that lead to different implementation of concurrent engineering:

Free updates

This is the organization where each designer deals with different part of the model, and it is free to update the model, as he places the components. PDMS can implement this organizattion by given an UPDATE access to the DESIGN database for each user. This makes the database to be updated also for all other designers as the work is saved.

The engineer have to lookup in the model for information, and to interact with it to place its parts. Clash detection can be activated interactively, or done from time to time in review meetings. When an error is detected the designers have to negotiate and decide what changes should be made. As the model is been contruct interactively, it is possible that the negotiation and decision occurs during the earlier phases, and the total number of errors are minimized. Figure 4. ilustrates this organization, where three desiners (DES1, DES2 and DES3) can read and write the 3D model, the interference checking is done as separate process.

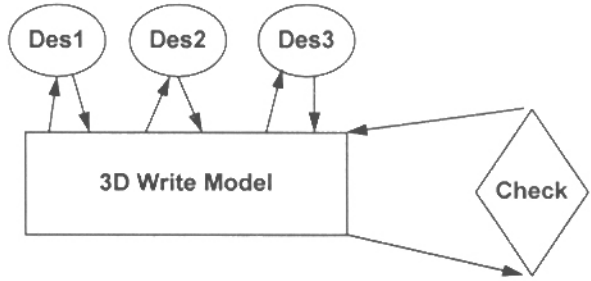

Figure 4. Parallel free model updates

Controled Updates

Controled Updates is a parallel design organization where there are two different types of 3D models, a master read-only model, and a writable temporary work copy of the 3D model. PDMS implements this organization by given EXCLUSIVE access permition to the database. After designers have finished their work, the manager checks the design and updates selectively the results to the Read-Only Master Database, so that all the others can detect the modifications.

The update to the Master database is done through a DTL file, this allows that only selected parts of the model can be updated. The parts that have interfered with others must be re-worked. This organization is very good for critical sites where a free update would generate too many modifications, although it generates the aditional work of reviewing and updating the model.

Figure 5 shows this organization where the interference check is used to verify and update the model.

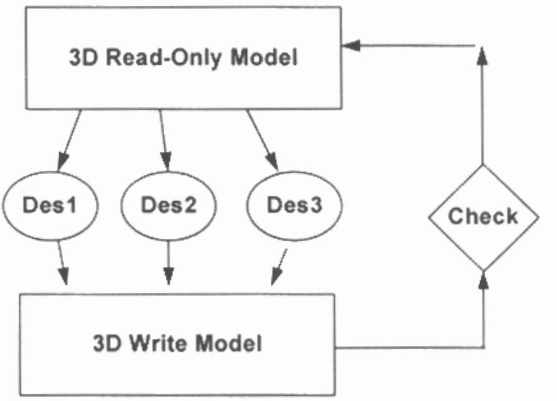

Figure 5. Controled Updates parallel organization

There can be assigned several levels of reviewing, updating and integration depending on the complexity of the model. From a ZONE integration, to a SITE integration that may require a team of experts to review the model. It is even possible to create the WORLD integrator, certifying the complete model is free of design errors.

Comparison

There are benefits and limitations on each form of organization. The serial organization is suitable for a simple modification, where very few interference are expected. If the design requires more interaction with the specialists, the free update organization seems better. If the site is very populatted with components, a more controled design organization is required. The controled updates organization has the advantage of the parallel design, in a more disciplined development, with the price of the need of an expert, to check and update the design.

Example

The advantage of using a concurrent approach to design a simple piping line is shown by figure 7 bellow. The difference in the time to complete a simple design, with a sequential and a parallel approach, is compared. Figures 6 show the evolution of design of a pipe-line connecting two equipments and its structure. The sequential organization (6a to 6c) exceeds the time to be completed when compared to the parallel one (from 6d to 6f).

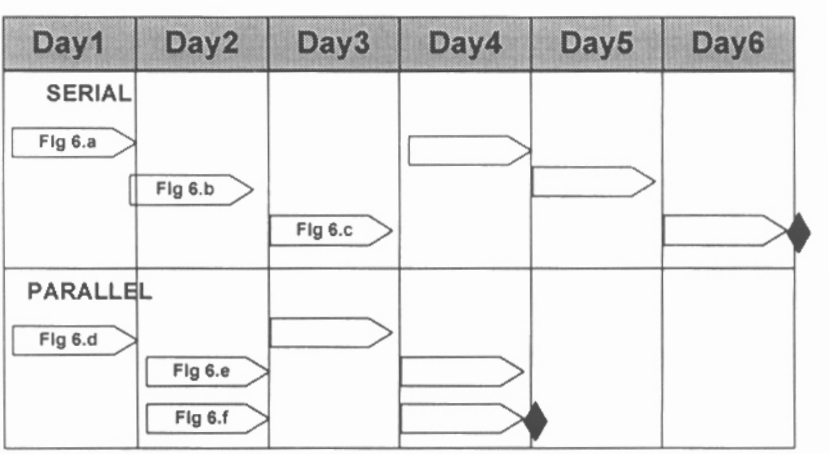

Figure 7. Timeline of the sequential and parallel organizations

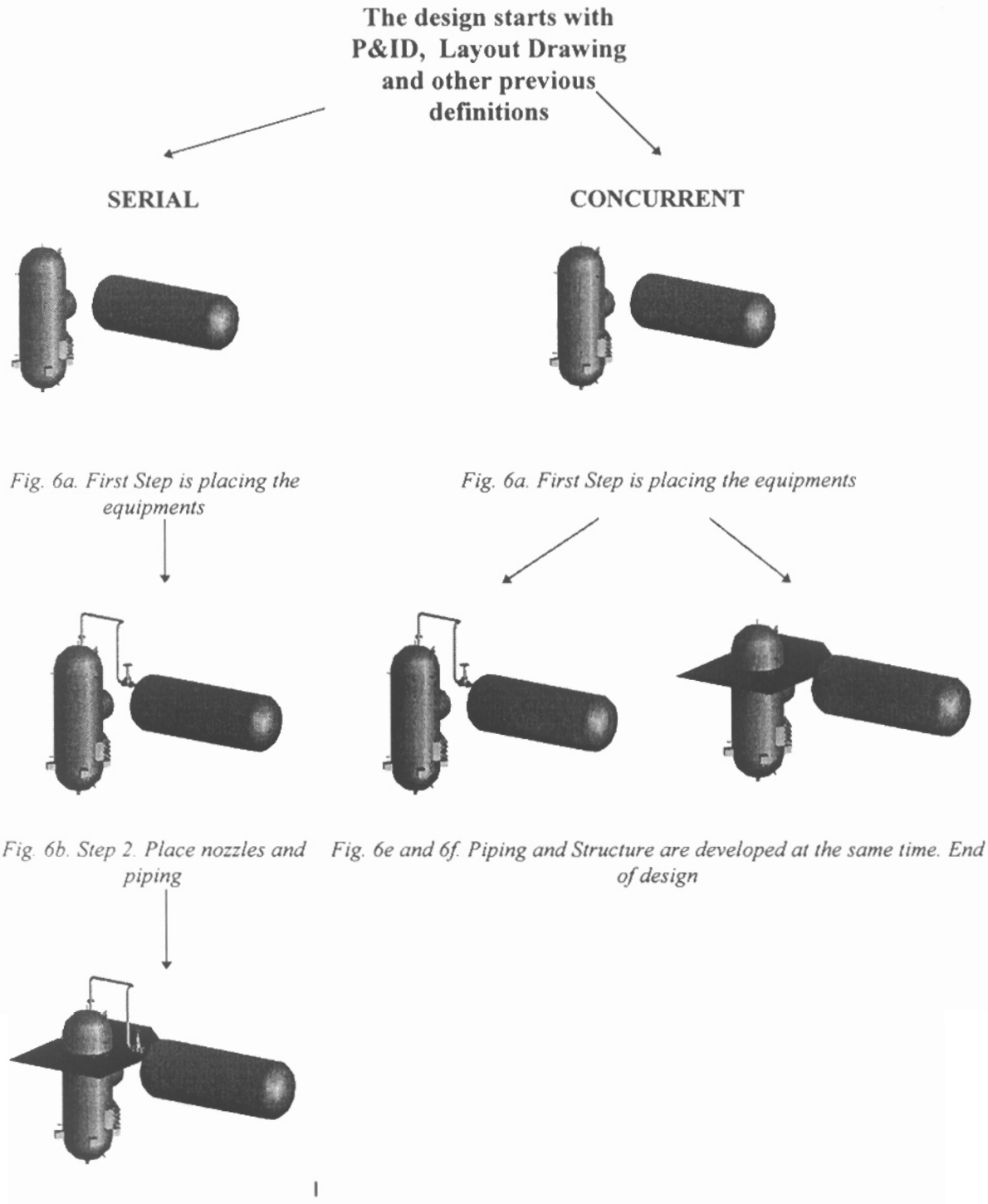

Figure 6: Comparison of a Serial and a Parallel design organizations for a small part of a plant, with two equipments, piping and structure.

Conclusions

Computers can be used not only as a productive tool for modeling and drafting, but also as a communication and managing tool. Communication is an important activity in the engineer's work. A CAD system is essentially a very specialized communication tool, but other forms of interaction among designers are need. It was observed that when the workstations are shared in the same room, face-to-face communication is used in the negotiation and decision phases. When workstations are distant, meetings and telephone calls are made necessary.The use of an E-mail or other related technologies are not enough explored and may solve this problem.

The study also shows that 3D CAD system has to improve its managing tools so that users can better organize their work. The use of external control devices, like modifying database access, have proved to be efficient. PDMS can implement database access managing tools in a more user-friendly form, and its is also desirable that PDMS develops interfaces with other managing tools.

Finaly, the study can conclude that the development of AEC design in parallel proved to be possible. The results of an integrated use of 3D CAD systems in AEC projects, allows that some principles of Concurrent Engineering can be adopted, with very promissing results.The success of its application to more complex models, where more disciplines are involved, relies on the ability of planners to divide the work in feasible phases, and also relies on the ability of the technical managers during the conflicts, that always occur.

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Acknowledgments

The authors want to thank Eng. C.E. Cerri and Mr. S. Autuori for their valious information on PDMS, and FAPESP - Fundação de Apoio à Pesquisa do Estado de São Paulo - for supporting this presentation.