Some conditions of implementing CE in advanced manufacturing systems

Joanna Kalkowska  
Poznan University of Technology  
Institute of Management Engineering  
Poznan, Poland  
e-mail: joanna.kalkowska@put.poznan.pl

Stefan Trzcielinski  
Poznan University of Technology  
Institute of Management Engineering  
Poznan, Poland  
e-mail: stefan.trzcielinski@put.poznan.pl

Abstract

Today the global marketplace is changing rapidly, industrialists have to enhance their strategy to respond to customers requirements and the market needs more efficiently and quickly. Some companies especially in Japan, USA and Europe have already started to implement techniques and tools that would enable them to respond more quickly to customers demand, delivering high quality products at reasonable costs. They also have invested heavily in computer aided manufacturing (CIM), advanced automation, robotics and information technologies. This activities change the organization of production and requires a new approach in company management and manufacturing process. Concurrent engineering seems to be the solution for the above problems. The paper presents some conditions of implementing CE in manufacturing companies mainly focusing on information technologies and team work.

1 Introduction to concurrent engineering

Simply, Concurrent Engineering (CE) is the simultaneous development of product and process. Many individuals, managers and scientists use a lot definitions of concurrent engineering. An important one was defined by the Institute for Defense Analysis, USA in 1986 and is following: “Concurrent engineering is a systematic to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause developers, from the outset, to consider all elements of the product life cycle cost, schedule and user requirements” [9, p.7].

Using CE approach the decisions about quality, costs and satisfying the customer expectations in all phases of the product life cycle are made in early stages of the product development. To get such effects a team working and advanced information technology is required [10, p.262]. Z. Weiss defined concurrent engineering as integrated design of products and following to them production processes considering all elements of product life cycle [11, p.5].

Implementing CE in company impose changes in management adopting to computer systems requirements. CE is also integrated set of management strategies guided to gain very high competitive product. The main aim of CE are:

- to reduce the time from “idea to market”,
- to rise the quality of product,
- to rise the quality of manufacturing process.

Achieve the full benefits of implementing CE to the company is possible only when a significant number of changes at all levels of
organization will be implemented. These changes can be summarized as follows:

- the introduction of multidisciplinary teamworking involving personnel from all stages of the new product development process such as finance, marketing, design, manufacturing and purchasing (including subcontractors),
- simultaneous design of the product and manufacturing process,
- the use of concurrent engineering tools such as QFD (Quality Function Deployment), CCM (Controlled Convergence Matrix) and DFMA (Design for Manufacture and Assembly) and others,
- the use of appropriate project management tools against clearly defined and agreed cost, quality and delivery targets specified to achieve complete customer satisfaction and business profitability. A fast and efficient communication structure is essential [2, p.72].

2 Team based working and Information Technology as a support for CE

Syan and Mennon [9, p.12] think that CE can be practiced without computer support and formal techniques. They said that the team members can input their expertise and experience and achieve good results without using any information technologies. Such approach presented by Syan and Mennon may be a denial of concurrent engineering concept. Team members skills are very important to achieve a success, but work of concurrent engineering teams will be less effective without using any computer support, advanced information and communication technologies or using formal CE techniques and methods.

Today, most of manufacturing companies have automated support for various functions such as the use of computer-aided design and computer-aided manufacturing (CAD/CAM) systems in design, engineering data management systems, etc. [9, p.13]. To ensure effective product development with using the above elements it is necessary to create a team. It is essential that these mentioned above facilities are integrated into the CE approach taken by companies to gain optimal benefit. Syan and Mennon distinguish four broad classes of support for CE, which are:

- process initiatives including team approach,
- computer-based support,
- formal techniques,
- data interchange methods [9, p.13].

Information technology (computer based support) and team approach at concurrent engineering are the considering subject of this paper.

2.1 Team approach

Team approach has a long history. Team approach was already known at twenties of XX century and it was treated as an important form of organization of production. The western countries started to be interested in team approach at sixties of XX century when E. Thorstudd published his research results realized at Norwegian companies. The results were applied in practice by Volvo and Saab. Such a positive results of implementing teams at Volvo and Saab was inspiration for other companies to use this method [3, p.16]. Parallelly to this success teams were also used by Japan automobile industry.

Over decades the teamwork had a number transformations. They have evolved from traditional teams through concurrent engineering teams to concurrent engineering virtual teams (figure 1). To ensure the most efficient benefits of their work, the team
members used different communication and information technologies while working. Figure 1 presents the evolution from a conventional team with using face-to-face meeting, to communicate to CE virtual teams which use advanced information technologies tools to communicate and design. According to Salomon [8, p.62], team is the participation of concerned departments as early as possible in the design cycle in order to maximize their contribution to the product and to its success in the marketplace. Next, Lipnack and Stamps defined team as group of people who interact through interdependent tasks guided by common purpose [5, p.6].

Concerning concurrent engineering, the traditional teams or virtual teams can be established. A virtual team is like traditional team. It also consist of a group of people but they can works across space, time and organizational boundaries with links strengthened by webs of communication technologies [5, p.7]. Concurrent engineering virtual team can be created while the team members works in terrain distraction or when the team consist also of customer or/and supplier. Uwe Muller [7, p.86] distinguished following features of virtual teams:

- virtual teams are not formal in static organizational structure, but they are formal elements in dynamic organizational structure,
- realize tasks which overcome possibilities of organizational units,
- consist of a specialists,
- works temporary, constantly or depending on situation,
- bear responsibility to the goals,
- fill in the existing organizational structure,
- team members have always given position in a formal organizational unit.

Some of those features are also available at conventional team for supporting concurrent engineering. Conventional team can consist of a different specialist and can realize tasks which overcome possibilities of organizational unit. The characteristic of a team is high level
of coordination. Coordination is achieving mainly by mutual adjustment and is only slightly supported by hierarchical supervision. Mutual adjustment requires both high expertise of team members and effective communication systems. More the team members are dispersed in different locations the higher need for IT to ensure the communication among them.

2.2 Information technology

Analyzing the concept of concurrent engineering method it possible to state that concurrent engineering is not efficiently used without information technology including CAD/CAM. To maximize the benefits of CE the advanced information technologies have to be permanently used. Information Technology in the design process is usually defined as computer-aided design (CAD) and computer-aided engineering (CAE). CAE is very broad term consists of many computer aids used in engineering including mentioned above computer-aided design CAD, computer-aided process planning CAPP, computer-aided manufacture CAM and inspection CAI, rapid prototyping RP, etc. CIM integrating the various activities which together form the manufacturing process e.g., design, production engineering, production planning and control, production scheduling, material requirement planning, manufacturing, cost accounting and distribution [10,p.265].

The CAD/CAM systems have the capabilities of three-dimensional shape modeling and the ability to derive physical properties like weight, center of gravity, etc. and to produce manufacturing data such as numerical control data and programme files. Among a lot of CAD/CAM system it is possible to distinguish the main following tools:

- 2D CAD – this level of CAD is entirely appropriate for non-complex designs and design documentation requirements. 2D CAD is a base for many 3D tools,
- 3D CAD – allows designers to see the outline of the parts in a three dimensional,
- Solids Modeling – most popular option for constructors and designers. It let to create shapes on the screen. Using this method, designers can see what they are actually design and can correct issues as they work,
- NC/CNC programming and simulation – tools that automate file translation into NC programming language such the result can be used directly by NC machine. These tools simulate the machining of raw stock so that machine operations are know prior, avoiding any machine errors, including scrap calculations, rapid prototyping - this tool allows the automatic conversion of data for rapid prototyping equipment. Rapid prototyping is used by the design team to understand the product in its environment. Early prototypes can be simple models. Some are carved from wax or clay to show the shape, other models are made by machining out plastics on CNC machine [8, p.149-151, 158-159].

There are a lot CAD systems available on a market like AUTOCAD, CADD, MEDUSA, SolidWorks, LogoCAD Triga, CATIA, Unigraphics and others. In the examples presented below some of those tools are mentioned as a tools supporting design under concurrent engineering.

Next to the CAD/CAM tools supporting concurrent engineering, there are also different information technologies tools which helps to communicate between team members. These are following technologies: email, fax, phones, mobile phones, video-conferencing system and others.

In 2002, dr Uwe Lukas from Computer Graphics Center – ZDGV in Rostock [6,p.5] did survey in German automotive industry to find out what kind of communication tools are used between virtual team members. The results shows that still telephone, email and
face-to-face meetings are important to communicate, however email and fax are not suitable for many offline discussion in engineering. The researches also shows that traditional mail is still used for sending data carriers and contracts (see figure 2).

**Communication tools between team members in german automotive industry**

![Communication tools between team members in german automotive industry](image)

*Figure 2: Use of communication technologies in the German automotive industry virtual team [6,p.5]*

### 3 Practical examples of simultaneous using teams and IT – mini study cases of different companies

In the content of conditions of functioning companies, there were carried out the analysis of those areas of companies which shows some features of concurrent engineering. The subject of this analysis were the following issues:

- the function of teamworking at product development and the tools supporting their work,
- application of advanced information technologies for design and manufacturing.

The detailed analysis of manufacturing companies in Poland have been embraced. Two examples of these companies are presented below.

Concurrent engineering team assume effective collaboration between constructors and technologist for fast product launch. Such effective collaboration is possible because of applying interactive tools which makes easier data exchange between team members. The teleinformatic infrastructure consist first of all of engineering applications which makes possible the modeling of a product. The specialist software (eg. CAD/CAM-2D, 3D) makes possible to replace physical prototype by computer model of product. Those computer models of product can be simulated. Such simulation makes possible modeling the geometry of a product and it helps to predict the exploitation details. Information technologies at concurrent engineering assure the access of all team members to the common data base what allows for simultaneous team design.

One to the most important changes determinant implementing concurrent engineering belongs establishing
interdisciplinary or multidisciplinary teams. Depending on the aims and work range, the team members can be selected from different organizational units. Such situation is shown at examples presented below. First example shows situation when a team is established to modify the product. Such teams are created in majority of manufacturing companies when some construction or technology problems has appeared. The initiate activities to create such a team is the complaint form the internal or external customer. Second example shows situation when a team is established to create a new product. The important thing is that teams in a both cases used different information technologies to support their work and/or communication.

**Company A\(^1\) mini case study**

Company A is a leader in manufacturing over 400 types and varieties of products including water meters, heat meters, rubber-seated gate valves, chlorinators, adaptor fittings. All those products have been designed and produced in conformity with the Polish and international standards, in accordance with the regulations and requirements in force on sales markets and with regard to the customers expectations. High quality and reliability of meters manufactured by company A have quickly gained recognition of domestic as well as foreign users and found their way to markets all over the world.

Export of this company is a development stimulating factor and makes 50% of the company total sales. The manufactured products are exported to over 35 countries of East and West Europe, the Near and Far East, Africa, both Americas and Australia. In relations with customers the following principles are strictly observed:

- proper recognition of customers' requirements and expectations,
- fast response to enquiries,
- attractive price offer,
- reliability of delivery terms and dates,
- high quality of products and service,
- partnership, confidence and openness in relations with customers.

This company runs research and development activity. The products are designed, manufactured and tested by the company. At figure 3 an example of a team which was created to modify construction and technology process is presented. According to the typology of teams\([4, \text{p.189]}\), this team can be typed as a team of work range. At presented company it is possible to distinguish teams that work on a design and running production of a new product as well as teams which members works on a modification of existing product. In case of concurrent engineering team, such a modification could consider changes in a product construction or changes in technological process. Within this company a problem has occurred that concerns the leakiness of manufactured products. To solve this problem, a team of 6 people from different departments has been established. The main task of this team was rationalization of implementing changes in construction and technological process.

To solve this problem the team members met twice face – to – face per eight hours. A constructor was a team leader. As a tool supporting solving problems they use ASPW method (elaborated by company A) inspired by FMEA\(^2\) (see figure 3) \([4, \text{p.} 189]\).

\(^1\) Because of the manufacturing character and the trade secret, the companies where the researches were made did not allowed to disclose their real names. For the need of this paper the author decided to use a letter symbol to characterize the companies.

\(^2\) FMEA – Failure Modes and Effects Analysis, a formal tool for concurrent engineering
The constructor used also special CAD tool called LogoCad Triga to rationalize construction. This tool is also used to design new products. The face-to-face meeting were not sufficient to solve the problem. During the whole time work the team members also used email and telephones to communicate.

**Company B mini case study**

Company B is the main supplier of automotive parts for European and world motor companies. Its main products are: clutch, brake and accelerator pedals and complete sets of these components, exhaust system, heater units and lead–brazen heater cores and other products. These products are manufacture on the basis of the following technical production processes: gas shielded and metal welding, metal plastic forming, metalsheet machining, metalsheet forming, electro–galvanizing and zinc coating, assembly processes and tool design in CAD-CAM systems assisted. At this moment company does not run research and development activity of their own. They mainly manufacture products on the basis of documentation delivered by the customer. According to the team typology [4, p.189], here is presented an example of concurrent engineering “new product team”. „New product team” is established in a situation when the new product is design and produced. The initiate activity to create such a team is the signed order from the customer. There are two kinds of possible order from the customer. First, is when the customer wants to order typical catalogue product and the second, when the product is not catalogue (see figure 4).

Before the team is fully established, the possibilities of manufacturing of ordered product are considered (the process of establishing team is partly started while the customer submit question offer to the company). Marketing department, construction department and technology department consider such possibility. If the answer concerns the possibilities of manufacturing the product is positive and client gave the signed order the “new product team” is fully created. The team members consist of the following specialists: constructor, technologist, marketing, finance, delivery, customer and sometimes supplier. In case of “new product team” a constructor is usually the team leader. During their work, team is controlled by a supervisor.

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3 LogoCad Triga - is a professional CAD solution which adapts to suit designer requirements, ranging from the user-friendly 2D CAD system through to the high-end 3D version, with industry-specific modules used in mechanical and plant engineering, as well as in industrial engineering.
Pararell to the „new product team” it is also created “FMEA team” which consist also of a team leader and a few members. The members are usual technologists, constructors and quality department representative. “FMEA team” is responsible for preparing and realisation of FMEA analysis before and after project concept, updating FMEA before the prototype is created, realisation and updating FMEA in a case of other activities. Considering a situation when company has to manufacture non-catalogue product without construction documentation delivered by customer, I would like to present the way and the course of team work using proper concurrent engineering tools (figure 4). This example shows a situation where customer gives only general overview of product which he wants to receive and from which raw material the product have to be manufactured. The design process can proceed like following. First, at 3D software (eg. CATIA, AutoCAD or Unigraphics), the constructor which is in permanent contact with the customer starts to create the product. Such a band between customer and constructor determinate the basis to involve the customer to concurrent engineering “new product team”. In case of using Unigraphics software constructor

4 Unigraphics- software which gives manufacturers a unique product development environment that helps create innovative, market-leading products. It is a comprehensive computer-aided design, engineering, and manufacturing solution that
designs the element and place it at XYZ co-
ordinates, which characterizes place of this
element at target unit or final element (see figure
5).

Figure 5: Example of design elements using XYZ
co-ordinates [adopted from Unigraphics]

In case of Company B, a few specialist
design eg. constrain beam which is applied at
some types of cars. The design process runs as
follows:

- 2 constructors design the individual
elements of beam,
- a technical specialist verifies technology
possibilities of manufacturing this
element.

All the informations concerning designed
elements are passed all the time through the net
between the team members. Next all the data are
delivered through the net to the central computer
where they are virtually assembled (see figure 6).

harnesses knowledge to drive innovation in both
product and process.

Figure 6: View of constrain beam (after virtual
assembly of all elements designed by the
individual constructors) [Example adopted from
Unigraphics]

After assembly all the elements to the
virtual model, the supervisor is appointed to
verify this model. Usually supervisor is main
constructor and/or main technologist. This
specialist verify construction correctness of
designed elements, conformity with all the
persons, dimensions, etc. and technologists
assess the manufacturing possibilities, which
elements should be manufactured by
subcontractors, etc. Ready design project
documentation including virtual model is send
to the customer, who puts on it (in Unigraphics
programme) the proper Unigraphics module
which is able to calculate and check durability,
tensions and conflicts. After verifying the
project, customer (with or without remarks)
send the documentation again to the company.
In case of this company the communication
team member-customer-team member is based
on a simply communication technologies like
telephone and email. However, 3D
documentation including virtual prototype etc.,
before is send to customer, firstly it is copied to CD disk and than is sent to the customer by courier mail. Such a practice is commonly used in company B because of data security. After implementing required corrections, receiving final approval of the ready project by customer, there are analysed elements which has to be manufactured by company. Documentation of these elements are transformed from Unigraphics for the construction pictures 2D. Such modificated documentation of each individual element is send by email, simultaneously printed and passed to the toolkit department. At toolkit department the physical die cavity are made and assembly in a press machine. Such prepared press is ready for manufacturing the elements. Next, the test production series is activated. Product of this series is delivered to the customer who tests this product of him own. After acceptance this series the correct production process is ensured.

This case presents a short example of team working using special Unigraphics software for design process. One of advantages of Unigraphics is that, it can be simultaneously available for a few workstations. So a few constructors can pararellly design different elements of required product, than to pass it to central computer (platform for collecting and data exchange), next to check assembly of all this elements. All assembled elements creates a virtual model (virtual prototype). This virtual prototype is virtually tested (simulated).

4 Remarks

Concurrent engineering is today a business strategy which replaces the traditional product development process with sequential design with a product development process where all the tasks are made simultaneously. This strategy focuses on the optimization and distribution of a company resources in the design and development process to ensure an effective and efficient product development process. The reasons that companies wants to use concurrent engineering is for the clear cut benefits and competitive advantage that concurrent engineering can give them. Concurrent engineering can benefit companies of any size. Companies that use concurrent engineering are able to transfer technology to their customers more effectively, rapidly and predictably. They are able to respond to customers needs and desires, to produce high quality products that meet or exceeds the consumer's expectations. They are also able to introduce more products at short time and to bring quicker upgrades to their existing products through concurrent engineering practices. Therefore companies use concurrent engineering to produce better quality products, developed in shorter time, at lower cost, that meets the customer's needs.

There are a number of companies from various industries which gained a lot of benefits because of use CE, eg. Rolls-Royce reduced the lead-time to develop a new aircraft engine by 30%, McDonnell Douglas reduced production costs by 40%, ITT reduced their design cycle time by 33% for its electronics counter measuring system [1]. Concurrent engineering is a approach concentrated on improvement of customer satisfaction through improved quality, reduced costs, faster product development and reduce time from “idea to market”. To ensure the above benefits of CE to the company , it necessary to use CE tools while product development process. Subject of this paper is mostly concentrated of team working and information technology. After literature review and review of company cases it is easy to notice that it exists close relation between team work and information technology. As a support for design activities, the team had a set of available information technologies tools which aid their communication, coordination and allowed to share of information between team members to increase team productivity.
The company management practice shows that the elements of CE can be visible at almost each manufacturing companies. Nowadays, CE method is still more popular at world industry (especially at automobile industry) than in Poland. At present, in Poland it is possible to find a companies which use in more or less scope the elements of concurrent engineering. The examples of companies presented in this paper reveals some of such elements like team working, information technologies, FMEA. This elements were used at each company at certain fields depending on situation. It was possible to notice that at mentioned examples conventional team as well as virtual teams were established. Team working and information technology were applied at those companies only at certain scope. Teams used a set of advanced information technologies tools to support design and communication. Anyway, at the age of rapid technology development, a traditional mail is still in use.

It seems that along with technology development and growing customer expectations, concurrent engineering method and solving problems by using team approach will be commonly applied at manufacturing companies. The proper selection of information technologies and the precise defined goals of company let to achieve advantage competitiveness.

The unavoidable invasion of more advanced and effective information technologies lead to fully automated manufacturing process in which human being will be only needed to give the concept of a required product and to supervise automation manufacturing process. Nowadays advanced concurrent engineering methods with all its formal techniques and elements as well as other modern managements concepts seems to be sufficient for managing company today. What new management concepts will be applied by companies in future? The concept of agile management could be the next step.

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