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The Important Role of Concurrent Engineering in Product Development Process

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ABSTRACT

Nowadays, Concurrent Engineering (CE) is becoming more important as companies compete in the worldwide market. Reduced time in product development process, higher product quality, lower cost in manufacturing process and fulfilment of customers' requirements are the key factors to determine the success of a company. To produce excellent products, the concept of Concurrent Engineering must be implemented. Concurrent Engineering is a systematic approach which can be achieved when all design activities are integrated and executed in a parallel manner. The CE approach has radically changed the method used in product development process in many companies. Thus, this paper reviews the basic principles and tools of Concurrent Engineering and discusses how to employ them. Similarly, to ensure a product development process in the CE environment to run smoothly and efficiently, some modifications of the existing product development processes are proposed; these should start from market investigation to detail design.

Keywords: Concurrent engineering (CE), product development process (PDP), CE principles and tools

INTRODUCTION

Concurrent Engineering (CE) is sometimes called simultaneous engineering, integrated engineering or life-cycle engineering, which is more a philosophy than a method (Tummala *et al.*, 1997). The concept of CE was initially proposed as a means to minimize product development time (Winner *et al.*, 1988).

Some common definitions are as follows:

> "Concurrent engineering is the extent to which product and process designs are generated simultaneously in the early stages of the product development process"
> (Koufteros *et al.*, 2001).

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Another definition of CE was presented by Junjie *et al.* (2006), as:

> "Concurrent engineering is an advanced manufacture technology in modern product design and development, which is a compact and concurrent systematic method of product design and its corresponding process (including manufacturing process and supporting process)."

Nowadays, CE is regarded as a key factor in determining the success of a company. CE involves overlapping various stages of developing new products to reduce delays. This reduction of delays is achieved by intensively implementing the CE principles. These CE principles have been cited as the main keys for the rapid new product development process and it was introduced by the Japanese firms (Bowonder and Miyake, 1993).

However, employing CE has not always been proven easy. As the popularity of CE grows and its applications have become more diverse, the core principles which define CE have become more and more vague. The CE approach is sometimes viewed as expensive in the short term, requiring resources and levels of commitment which may not be available.

According to Sapuan (2006), implementing the CE can reduce costs, shorten the time of product development process and improve product quality (CTQ), if all design activities are performed in a parallel manner and the decision making among different groups are integrated. However, CE does not mean a simultaneous undertaking of all activities in the product development process at the same time.

The objectives of this paper were to present the findings of the research on the use of CE in the product development process, review several CE principles and tools in solving product development process problems as well as propose some modifications of the existing product development process.

CONCURRENT ENGINEERING (CE) VERSUS SEQUENTIAL ENGINEERING (SE)

The method where each design phase mostly starts, when the previous one has been completed, is called sequential engineering' (SE), as shown in *Fig. 1.* The SE can also be defined as a process, in which different stages such as customer investigation, product design specification, detail design, manufacturing, and testing are separately and sequentially conducted (Portioli-Staudacher *et al.,* 2003). Therefore, some problems which may arise during product development process may cause the need for the product to be redesigned and this redesigning activity will increase development time and cost of the product (Bhuiyan *et al.*, 2006). Moreover, a critical issue in this approach is how much the requirements and design have been modified in order to be finally accepted for manufacturing and production. These factors will weaken the competitiveness of products (Kamrani and Vijayan, 2006).

In order to improve the efficiency of the product development process, CE approach must be implemented; this is shown in *Fig. 2.* In this method, all the activities in the product development process are integrated and run in parallel with the feedback when needed, and

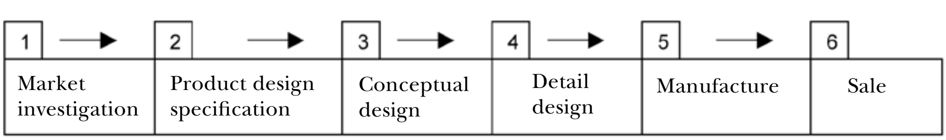

Fig. 1: Steps in product development process with serial engineering

the information and CE tools continuously flow along with all the activities in the product development process. Consequently, many of the problems which can occur under the sequential engineering process can be completely prevented after a proper consideration.

A recent study carried out by Bhuiyan *et al.* (2006), by means of comparison between the CE and SE projects in terms of process, tools and technology, communication, time to market, project performance, etc., showed that the use of the CE project was more successful than the SE project at Telcom, where tremendous improvements in terms of time to market, project development, cost and product quality were achieved.

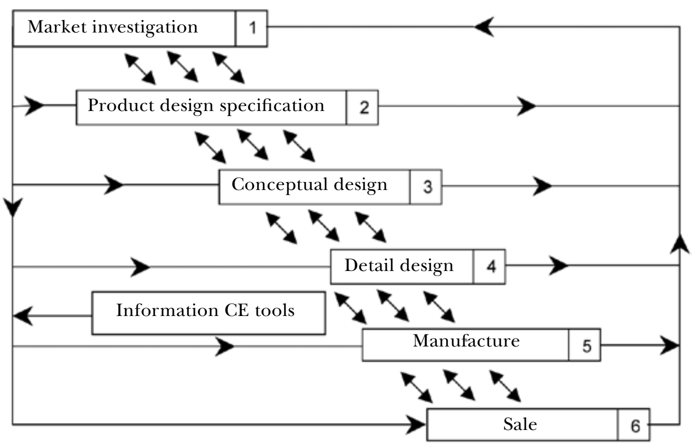

Fig. 2: Steps in product development process with CE environment

THE PRINCIPLES OF CE

In general, CE principle can be divided into three key factors which can contribute to time reduction, cost reduction, improve product quality and fulfil customer's need, as shown in *Fig. 3* (Portioli-Staudacher *et al.*, 2003; Kalkowska *et al.*, 2005; Bhuiyan *et al.*, 2006).

People

In the CE approach, utilizing the appropriate human resource at the right time is critical and it accelerates development by keeping rework to a minimum. To be successful in CE implementation requires some factors have to be considered as follows:

i. Teamwork

Team work is the basic principle of the CE (Lettice *et al.*, 1995; Kusar *et al.*, 2004). Teamwork emphasizes interpersonal relationship, cooperation, negotiation and collaboration decision making. Teamwork is an integral part of CE, as it represents the means for organizational integration.

ii. Multidisciplinary teams

CE is based on multidisciplinary product development team. Multidisciplinary teams, involving experts from all stages of the product development process such as design, process, production, marketing, manufacturing, etc., are very important in order to

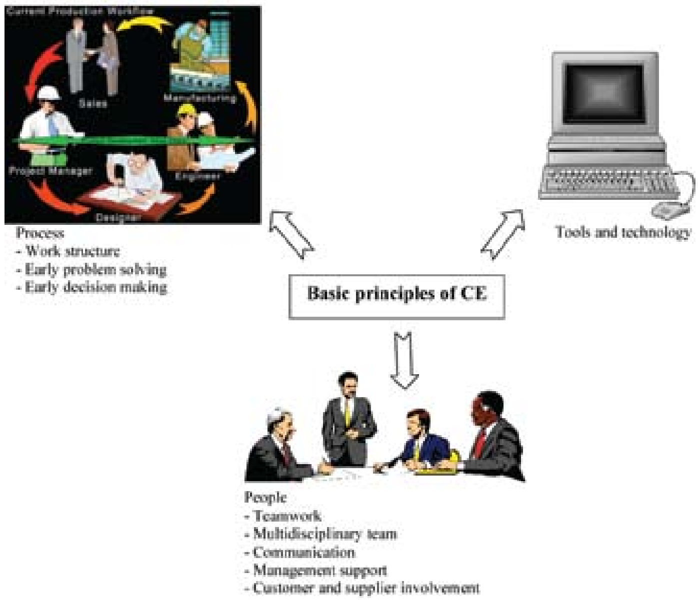

Fig. 3: Basic principles of CE

succeed in CE implementation. Multidisciplinary teams can break down the barriers between departments and provide effective means of communications.

iii. Communication

Communication is the basic principle for success in CE. Teams will work better if they know what other members are doing. Team members have regular meetings which allow fast and efficient exchange of information (Kusar *et al.*, 2004). Communication between suppliers, customers and manufacturer is also a basic principle in the implementation of CE at the early stage of product development process (Portioli-Staudacher *et al.*, 2003; Hamid *et al.*, 2005). However, according to Bhuiyan *et al.* (2006), less communication can result in less time spent and lower the potential for confusion.

iv. Management Support

According to Abdalla (1999), the main problem during practicing CE was the commitment of management in implementing CE. Thus, the lead and support from the top management is important to realize the implementation of a successful CE. The top management must not only support the CE initiative, but also actively participate in formulating and implementing the CE goals.

v. The Involvement of Customers and Suppliers

In designing and manufacturing a product, the integration between the customers, suppliers and manufacturer is essential in determining the success of a product. This CE principle can reduce a significant portion of design error and rework due to misunderstandings or miscommunication between the company, the customers, and the suppliers, at the early stage of product development process.

Process

A key in implementing the CE approach is to have a single well-defined process with clear ownership and goals. Thus, the process and the related schedule of activities must be based on some basic principles, as follows:

i. Work structure

In general, all activities in product development process must be performed in a parallel and simultaneous approach. In order to construct a clear work structure or framework, some factors have to be worked out such as defining and formalizing the CE process, defining overlapping activities, identifying process ownership and setting goals clearly.

ii. Early Problem Discovery

Problems which are discovered at the early stage of the product development process (particularly during the first 20% of the cycle time) are easier to solve than those which are discovered later.

iii. Early Decision Making

The 'window of opportunity' to affect a design is much wider during an early design stage than in a later stage, i.e. when some of the decisions are frozen and the design is matured.

Tools and Technology

An appropriate set of tools and technology should be chosen to help achieve the maximum benefits which enable integrated product development. For an effective CE implementation to be accomplished, the use of tools and technology is greatly required. However, there are two aspects which need to be considered when implementing the tools and technology; firstly, the tools and technology which enable an effective implementation of CE need to be identified, and secondly, people who will use these tools and technologies should be trained.

PRODUCT DEVELOPMENT PROCESS WITH CONCURRENT ENGINEERING

Concurrent engineering (CE) is a very important concept in the world of new product development. It is a methodology used for creating timely products, while maintaining the highest quality, lowest cost and most customers' satisfaction. In conventional product development, activities such as market investigation, product design specification, conceptual design, detail design, manufacturing and sales are sequentially performed and the trend is to complete 100% of each stage before performing the next. In this approach, a large number of modifications have to be made in the later stages of the product development process. Consequently, this can contribute to the increase in the time and cost involved in the product development process. Meanwhile, CE is a systematic approach to integrate all the design activities, and it provides a framework to make changes in design.

Basically, product development process is a process for translating customers' requirements into product design and manufacturing. Product development process provides a roadmap to designers for the activities or processes and deliverable required in designing, developing and manufacturing a particular product. The main objectives of a product development process are to minimize the life-cycle cost, maximize product quality, as well as maximize customers' satisfaction, maximize flexibility and minimize lead time (Mazumdar, 2002). Product development process can be categorized into two main processes, firstly, deal with development of a product and secondly, deal with its production (Kusar *et al.*, 2004). However, this paper only describes the development of a product, which is initially started from market investigation up to the detail in the designing stage.

In the literature, there has been no standard product development process or designing process in the context of the CE environment. Nevertheless, various product development processes, within a CE environment, have been developed and proposed in the literature. There are a number of well-known and established product development models which are being implemented by most product designers or engineers, such as the Pugh's model (Pugh, 1991), Pahl & Beitz' model (2007), French's model (1985) and Shigley's model (Groover and Zimmers, 1984). These models are intended to be general and aim to guide designers to traverse a series of design stages and carry out a number of design activities in order to understand and solve design problems. These models are included under the umbrella of CE. However, most product development models developed, as mentioned above, merely provide a guideline or design flow to assist designers or engineers in performing designing activities, but they still lack in terms of addressing the CE tools, which is a key factor to success in the new product development in the CE environment.

The design flow of the product development process used in this research was based on the total design method or the Pugh's method (Pugh, 1991). This method has widely been used by most designers or researchers in developing a new product or automotive components. However, this method does not specifically show development in terms of the CE tools needed, but are rather descriptive of design activities; whereas, the CE tools and its flow are key elements which must really be addressed in the product development process in the CE environment. Sapuan (1996) criticized on the sequential flow of the designing process and stressed that the concept of CE must be implemented in a clear manner in this method.

There are some examples which show the importance of addressing the use of the CE tools in product development process under the CE environment in the literature. Among others, Sapuan (1998) developed a concurrent engineering design system for polymeric-based composites automotive components. The system was developed in order to assist designers to determine the materials which would satisfy a set of pre-defined design constraints, particularly in terms of reduction of weight and cost. The system comprised the integration of various CE tools, such knowledge-based system (KBS), solid modelling, material database and design analysis tools. Meanwhile, Yan (2003) developed an innovative design process model for a computer-based engineering design through an integrated and coherent use of computer-aided design (CAD) systems. The design approach which was based on the computer multiperspective modelling and evaluation derived from the above design process model could provide a comprehensive and integrated design support for various engineering design activities. Rozlina *et al.* (2004) proposed a product development model by integrating various CE techniques such as quality function deployment (QFD), morphological chart, concept convergence and design for assembly (DFA). The proposed model allows users' requirements to be identified, generates various design concepts and its evaluation; based on which, the chosen design is then optimized for manufacturing assembly. Thus, it has been proven that the CE tools should be clearly addressed at every stage of product development process under the CE environment.

A literature review of the existing studies shows the importance of addressing the CE tools in product development process, and none of the above researchers have addressed the use of the CE tools in their proposed product development process, i.e. starting from market investigation until the detail in the designing stage. To overcome these limitations, this paper proposed a model which could provide some basic steps in the CE tools required, starting from market investigation to detail design in order to assist design teams to perform their design activities more effectively and efficiently.

The Proposed Modification of the Modelling of Concurrent Engineering System in Product Development Process

Product development process can be further divided into two main processes; firstly, it deals with the development of a product and secondly, it deals with its production (Kusar *et al.*, 2004). It has generally been known that approximately 80% of the manufacturing cost of a product is determined by the design of the product (Mikkola and Skjoett-Larsen, 2003). Thus, this paper only describes the development of a product which is started from market investigation to detail design. *Fig. 4* shows the product development process being practiced by most manufacturers; this process does not specifically show development in terms of the CE tools needed, but it is rather a description of the design activities. Meanwhile, the CE tools and their flow are key elements which must really be addressed in the product development process in the CE environment.

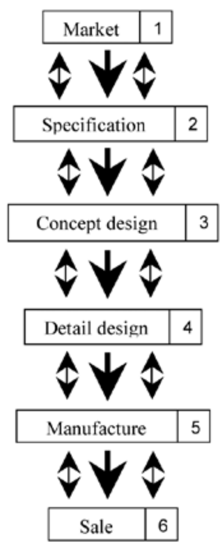

Fig. 4: Total design activity model (Pugh, 1990)

The proposed model of product development process in the CE environment is shown in *Fig. 5*. Several CE tools should be addressed and implemented to produce a product with good quality. Typically, all designing phases in this model are operated in parallel, simultaneously and iteratively but systematically operating within the design phase will minimize unnecessary iteration. From this proposed model, those who are involved in the product development process - begin with market investigation and end with detail design - will be able to understand the process flow of the product development in the CE environment. The proposed product development process, in the CE environment process, consists of four main phases, as follows:

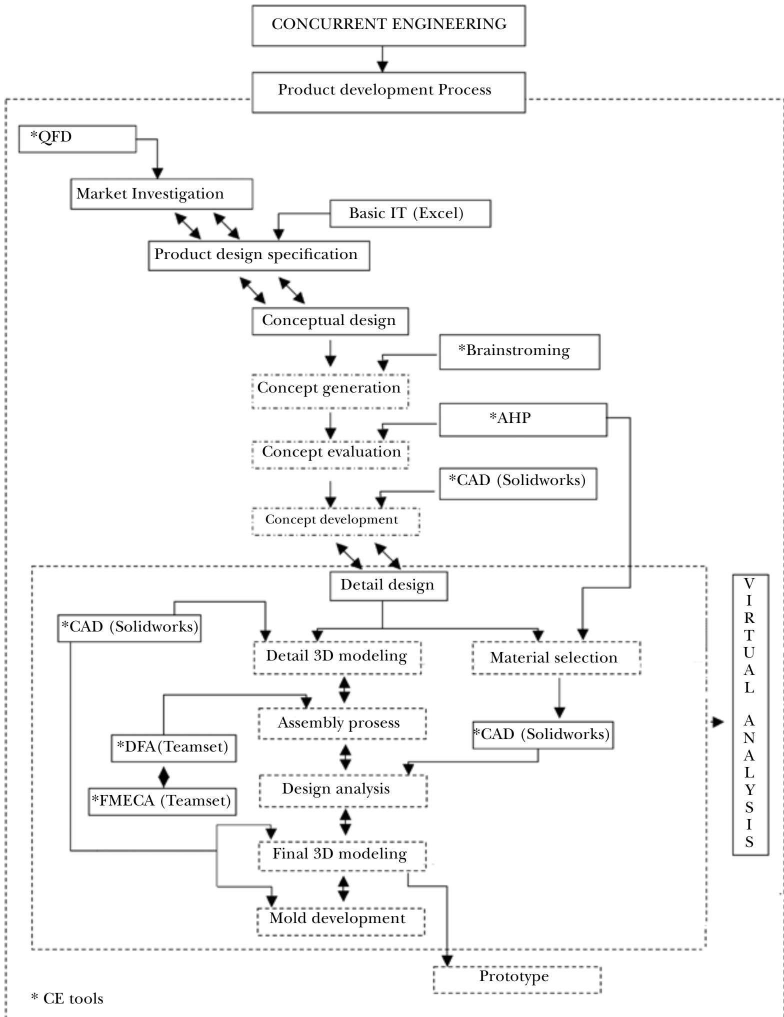

Fig. 5: Proposed product development process with CE environment

i. Market investigation

Market investigation phase is the first step in product development process and it is essential in determining the success of a product. There are many products which have been reported as unsuccessful in the marketplace because they do not meet the customers' expectation (Cooper, 2003). It is necessary to implement a tool which can ensure a better understanding of the customers' needs and requirements. One of the useful and familiar methods is quality function deployment (QFD) (Hsiao, 2002; Chen and Yang, 2004). QFD is a customer-oriented approach to product development. It supports design teams in developing new products in a structured way, based on the assessment of customers' needs.

ii. Product Design Specification (PDS)

The design specification or product design specification (PDS) is constructed after analyzing the marketplace and customers' needs. PSD is a document prepared early in the product development process; it sets out the requirements which the design will have to satisfy. In a way, PDS acts as the control for the total design activity because it places the boundaries on the subsequent designs (Pugh, 1991). As PDS is a control document, basic computer applications have to be employed.

iii. Conceptual Design

Conceptual design is carried out within the envelope of the PDS. The conceptual design phase is more essential as compared to other design phases in product development process. This is because it forms the background work and involves many complex evaluation and decision making tasks (Sapuan, 2005a; Xu *et al.*, 2007) at this stage. In general, conceptual design consists of three steps; these are concept generation, concept evaluation and concept development.

– Concept Generation

One of the tools which can generate ideas to meet the PDS is brainstorming. This method involves generating ideas, which is typically done in small groups. By the end of a brainstorming session, there will be a list of ideas, most useless, but some may have the potential to be developed into a concept. This brainstorming session can work better if the most of the teams have different areas of expertise.

– Concept Evaluation

Once a suitable number of concepts have been generated, it is necessary to choose the most suitable design or alternative to fulfil the requirement to set out the PDS. There are many useful tools to be used in evaluating and making the best decision; these include expert system, fuzzy logic, neural network, analytical hierarchy process, etc. In the concept development phase, the chosen concept or alternative can be further developed in detail.

– Concept Development

After evaluating and decision making have been accomplished, the product should be developed in detail. At this phase, the CE tool such as the computer aided design (CAD) is essential and it must be implemented actively. The chosen concept design is designed in detail, by considering all the dimensions and specifications until the final design is carried out.

iv. Detail Design

At this phase, 3D modelling must go through five processes before the product can be manufactured. This 3D modelling and material selection analysis must be performed simultaneously, as shown in *Fig. 5*. The CE tools (such as computer aided design, or CAD) have to be applied so as to create a detail 3D modelling and for design analysis purposes. The products which have a number of parts must be analyzed using design for assembly (DFA) method in order to reduce the number of parts which are not necessary to be manufactured. After that, the product will be analyzed by employing failure mode effects critical analysis (FMECA) to evaluate the potential failure of a particular product or process. Based on the results gathered from the material selection, the 3D modelling must be analyzed to ensure the selected material is able to be manufactured easily. Then, the final detail of the 3D modelling, using the CAD, will be carried out once the design analysis is completed. Finally, the mould design of the product will be developed using the CAD applications. Generally, all the processes in the detail design phase are known as the virtual analysis because all these designing aspects can be simulated and analyzed using design simulation software.

CONCLUSIONS

This research supports the claims that CE is very important in product development process. The application of the CE concept and its tools in the product development process can help the designers to manufacture products more efficiently and effectively. The firms which have been implementing CE tool in their product development have gained tremendous benefits, particularly in terms of reducing cost incurred, reducing time for product development process, improving product quality and fulfilling customers' requirements. Moreover, some design uncertainties can be reduced using this method, and the product can be designed in a more transparent process.

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