CONCURRENT ENGINEERING: AN OVERVIEW REGARDING MAJOR FEATURES AND TOOLS[1]

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Summary

Concurrent engineering is a methodology of work based on the parallelization of tasks - that means, to perform tasks concurrently. It refers to the approach used in product development in which the functions of design engineering, manufacturing and others, are integrated to reduce the total time required to bring a new product to market. It interacts with all elements of the product life cycle, from conception to disposal, including quality, cost, schedule and customer requirements. The concept of Concurrent Engineering has become much more comprehensive and should include cooperation and consensus among those involved in development and using computational resources (CAD / CAE / CAM / CAPP / PDM) and methodologies (DFx, QFD, etc.). The goal of this paper is to show the current state of the art and propose new directions for future research in CE giving special relevance to customer and process requirements as well as time restrictions and quality constrains.

Key words: *Concurrent Engineering (CE), New Product Development (NPD), Product lifecycle Management (PLM), Design structure matrix (DSM), Supply Chain Management (SCM), Quality Function Deployment (QFD).*

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1. INTRODUCTION

The definition of concurrent engineering (CE) was first introduced in 1988 (Winner et al., 1988), by the institute of defense analyze (IDA), and has since been the choice of many companies to reengineer their business process and carry out integrated management system which take into consideration quality, career, health, safety and environment (Chen, 2007; Chimay et al., 2002). CE is commonly regarded as a systematic approach to integrate concurrent design of products and its related processes, including manufacture and support processes (Ostwald and Jairo, 1997). As an engineering and management philosophy, which also deals with the life cycle issues of a product, the most distinguishing feature of CE is the multidisciplinary, cross-functional team approach. As a direct consequence, palpable improvement in quality, time, cost, etc. has been achieved by those enterprises that have applied CE (Chen, 2007). CE applications were reported to achieve a 30–60% reduction in time-to-market, 15–50% reduction in life cycle costs and a 55–95% reduction in engineering change requests (Fine et al., 2005). While enjoying the enhancement of productivity, those enterprises also found that the implementation of CE has resulted in a series of problems due to the simultaneous execution of different work phases (Chen et al., 2006). CE complicates the management problem as it requires joint optimization of a more complex objective with a larger set of constraints. CE is based on the idea of carrying out as many stages of project operation concurrently as possible, rather than in a sequential order. It calls for the formation of a cross-functional team, which includes people from a wide range of departments. As decision-makers, group members in multi-discipline team usually come from different disciplines and have different discipline knowledge, thus their objectives are different (Chen, 2007; Fine et al., 2005). Furthermore, a series of issues, which are critical for the successful implementation of CE, including organization, technology, manpower, etc., must be changed to cater for the characteristics of CE (Chen et al., 2006; Chimay et al., 2002; Khafan and Anumba, 2000; Rosenblatt and Waston, 1999; Vincent and Gavriel, 1998). These issues will definitely add extra cost to projects.

One of the major problems that CE faces is concerning the evaluation of performance which is due to different factors addressed by several authors. Given the definition of CE we can expect to overlook different tasks running simultaneously which frequently do not fit the evaluation requirements (Chen, 2007). Tasks are intertwined and therefore complex to evaluate (Chen et al., 2006). Also, the interaction of different departments and the variance of evaluation criteria contribute even more to the challenge of evaluation (Koufteros et al., 2001;Zhang et al., 2006).

Attempts to model and evaluate CE have been addressed in the literature according to different approaches. Methods have been designed using computer simulation models such as MATLAB and SLAM in order to simulate the complex interaction of tasks (Lu et al., 2005). Information theory methods have also been used to measure entropy of processes (Kryszkiewicz, 1998). Rough Sets and Artificial Intelligence have been applied to deal with uncertainty and process modeling (Dai et al., 2008; Sarkar, 2002; Xu, 2002). Other methods such as the Grey theory method (Dang et al., 2005; Liu and Lin, 2006) and the Data Envelopment Analysis (DEA) (Qiu and Ye, 2005; Wei and

Zhou, 2006) have been used to perform CE performance evaluation. Results of performance evaluation have not been consensual and additionally are usually unilateral which cannot reflect the overall situation of system due to the limited perspective.

2. MAJOR FEATURES CONCERNING CONCURRENT ENGINEERING

When describing concurrent engineering there are several aspects or features that have to be considered. In the following description an overview of different aspects that are pertinent to the analysis are pointed out and considerations made upon performance evaluation of concurrent engineering. Cross-functional teams that include members from various disciplines involved in the process, including manufacturing, hardware and software design, marketing, quality is crucial in CE. This philosophy is built on the synergy between its agents, who must work in multifunctional teams, joining people from different areas of the company. Working in several processes /activities at the same time is critical to reducing design time, increasing productivity and product quality.

The new product development (NPD) describes the complete process of bringing a new product to market. A product is a set of benefits offered for exchange and can be tangible (touchable) or intangible (a service or experience or belief). There are two parallel paths involved in the NPD process: one involves the idea generation, product design and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

The product lifecycle management (PLM) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise.

Supply Chain Management assumes fundamentally that companies should define their competitive strategies and functional through their positions (both as suppliers and as consumers) within the production chains in which they operate. A basic goal in SCM is to maximize and realize the potential synergies between the parts of the production chain - including the company's relationship with its suppliers and customers - to meet the end user more efficiently, both by reducing costs, such as by adding more value to end products. Examples of cost reduction: by reducing the volume of transactions and information papers, the cost of transport and storage, and decreasing the variability of demand for products and services, among others. More value has been added to products through the creation of customized goods and services.

Effective Practices in SCM have been implemented worldwide, which have aimed to simplify and achieve a more efficient supply chain. Positive results have been obtained mainly through procedures such as: Restructuring and consolidation of the number of suppliers and customers; Division of information and integration of infrastructure with customers and Related Searches; Joint development of products; Logistical considerations in the development phase of products; Integration of competitive strategies in supply chain.

Benchmarking can be defined as the search for best practices that lead a company to maximize business performance. Also, Benchmarking is the continuous process of measuring products, services and practices in relation to the strongest competitors or the companies recognized as leaders in their industries. Benchmarking leads to understanding the position of a competitor, but not to the creation of practices beyond those of competition, which will be attained only by the discovery of best practices, wherever they are (other types of organizations, not only competitors).

Modular products are products, systems or components that perform their tasks by combining different modules. The modules are components, subsystems and modules that interact with different ways resulting in different product variants. Besides, modularity allows the production of different products by combining standard components. The modularity makes possible to have a wide range of products with quick responses to changing consumer needs and desire.

With modular product structure, engineers have more freedom to design their modules without direct dependence on other stages of the project. Due to this independence, increases the intensity of innovation in design, as engineers can create and test different solutions within their own modules, respecting only the visible rules or system interfaces. Another immediate consequence is the fastest range of solutions improved as problems are solved more easily. With this method, the suppliers have their role in the process of product development achieved due to the independence granted to them. Furthermore, the modular product facilitates the logistics / distribution with the decrease of suppliers, through the delegation of smaller subsystems suppliers of modules.

The Lean Production is a method that follows some general characteristics: (a) Flexible manufacturing, with a smaller number of specialized machines, (b) Inventory reduction, (c) Ttraining of qualified employees and multi-tasking prepared to work in teams, (d) Manufacturing lines prepared to prevent failures and avoid final repairs, (e) Relationship cooperation and long-term suppliers. Superior performance in product development resulting from the lean mode will only be transformed into competitive advantage for the company if the entire administration is focused on this. That means, having the assembly line and production, supplier relationships and treatment with consumer operating in agreement and in accordance with the rules of lean production mode. In product development done in lean organizations, there is an emphasis on cross-functional teams with strong leadership, and with active participation of experts from various functional areas being reclaimed by the performance within the team. The consequence of this focus on lean product development is the ability to design and produce a greater variety of products given the fragmentation of the market, achieving customer loyalty by quality and reliability of products representing for organizations large productivity jump, product quality and rapid response to cyclical market demands. The companies that dominate the lean design have competitive advantages because they can expand their product range, reaching the best market segments.

3. TOOLS APPLIED TO CONCURRENT ENGINEERING

There are several tools commonly used in Concurrent Engineering with the aim of improving schedules and execution, measure performance and model process management. In this section some of the tools that are considered most important are presented:

The Quality Function Deployment (QFD) is a technique generally used in the product development process in order to orientate the development team to incorporate the real needs of customers in the design (VOC – Voice of Customer). The strength of QFD is to make explicit the relation between customer needs, product characteristics (engineering specification) and parameters of the production process, allowing prioritization and harmonization of the various decisions taken during product development as well as enhance teamwork.

The critical path method (CPM) is used for scheduling a set of activities in project management. To apply CPM it is needed to construct a model of the project that includes a list of all activities required to complete the project, the time (duration) that each activity will take to completion, and the dependencies between the activities. Using these values, CPM calculates the longest path of planned activities to the end of the project, and the earliest and latest that each activity can start and finish without making the project longer – called as critical path. This process determines which activities are "critical" (i.e., on the longest path) and which are "not" (i.e., can be delayed without making the project longer). In project management, a critical path is the sequence of project network activities which add up to the longest overall duration. This determines the shortest time possible to complete the project. Any delay of an activity on the critical path directly impacts the planned project completion date. A project can have several, parallel, near critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.

The design structure matrix (DSM), also referred to as dependency structure method, dependency structure matrix, problem solving matrix PSM, incidence matrix, n-square matrix or design precedence matrix, is a matrix representation of a system or project. The approach can be used to model complex systems in systems engineering or systems analysis, and in project planning and project management. It enables the user to model, visualize, and analyze the dependencies among the entities of any system and derive suggestions for the improvement or synthesis of a system. As a management tool, DSM is most commonly applied in project management, and it provides a project representation that allows for feedback and cyclic task dependencies. This is extremely important since most engineering applications exhibit such a cyclic property. As such, this representation often results in an improved and more realistic execution schedule for the corresponding design activities.

Design for Manufacture (DFM) refers to the simplification of manufacturing the product while the Design for Assembly (DFA) techniques focus on simplifying the product, as well as, reducing costs. In general, Design for Manufacture and Assembly (DFMA) analysis is used in the manufacture of products. In this case the product is disassembled and assembled again emphasizing the time and handling costs and junction of components. DFMA can also be used during the development of a product.

4. THE PRESENT STATE OF CONCURRENT ENGINEERING

In the quality supply chain the current studies refer to the implementation of a systematic of mass customization (Chen and Tseng, 2008) based on supply flexibility and demand. For this, it is proposed the negotiation with the client using a new methodology, supported by the use of algorithms, to align demand and supply flexibility by the co-design of customized products. The term supply flexibility is dependent of customer since it is connected to how much the customer authorises to loose in terms of product features to earn in price/costs and delivery situation, if properly aligned.

To integrate the tool QFD in the methodology new product development (NPD) (Tang et al., 2005) it is proposed a software system of Evaluation and Selection of Supplier Involved Part Design (ESSIPD) in order to make easier the application of the method of selecting suitable alternative design solutions for a part came from the suppliers involved in NPD during the part deployment phase. Continuing on NPD, recent studies (Valle and Vazquez-Bustelo, 2009) refer to the link between the use of concurrent engineering (CE) and success in new product development (NPD) which is considered an important factor for achieving sustainable competitive advantages. Researchers and managers are always looking for methods and practices in order to make better NPD processes, especially effectiveness or success. Those studies are based on varying conditions of uncertainty and complexity focus on radical versus incremental innovations. As conclusion it is observed that by the use of linear regression, the results obtained indicate that overlapping activities, inter-functional integration and teamwork positively affect NPD performance in terms of development time and new product superiority when referred to incremental innovations. When referred to radical innovations, the improvements obtained are linked to development cost.

Referring to the Product Lifecycle Management (PLM) there are many studies presented. Each one refers to different aspects. In order to obtain short time-to-market for introduction of a new product into the market early, it is proposed a full scenario of technology solutions (Ming et al., 2005) for PLM based on the full analysis of business drivers, industry requirements, and review of the actual state-of-the-art related to PLM. The main focus is to bring customers into the design chain with the target of achieve shorter product lifecycles and higher levels of customer satisfaction. In another scenario, it is presented to a product structure model: a software application designed for developing product lifecycle management systems (Ni et al.,2008) which is capable of keeping a separation between product family structures and variations and reinforcing own consistency. The main goal is the modeling and designing a PLM system which can be easily converted with minimum redesign and redevelopment when implemented in other companies and, also, minimum reconfigured for different business cores.

Analysing the PLM standardization (Fan et al., 2008), the standard body Object Management Group (OMG) issued a Request for Proposal (RFP) – year 2005 -

for implementation of an international standard for Knowledge Based Engineering (KBE) Services for Product Lifecycle Management (PLM). KBE represents the encoded knowledge of the enterprise and there is a quest to systematically manage this knowledge, preferably using the same PLM technology that is being used to manage product information. The standard will make easier the integration of KBE applications in a PLM environment. In last time the majority of CAD vendors initialise to incorporate KBE functionalities in own products.

Referring to Product development process modelling (Huang and Gu, 2006), it is important to consider the product model and process model. The coupling of both aspects is very important for the final product and for the controlling of all process flow. And, also, it is important to empower a multifunctional team to develop product concurrently and cooperatively. It is developed an integrated development architecture, which is based on the detailed analysis of coupling relations between the product model and its corresponding process model. For finalizing, the interrelationships and coupling mechanism between product model and process model are analyzed and established, and the algorithm developed allows evaluate the model coupling effect.

Pushed by OEM (Original Equipment Manufacturer) and suppliers that are going to establish the virtual enterprise in order to achieve improved products in shorter time, a scenario for collaborative project management (Wang et al., 2008) with supplier involvement is proposed for development out-sourced or off-shored parts considering the main questions: "What to collaborate"? "How to collaborate"? This scenario refers to a model and related system architecture of project collaboration between the company and suppliers that have been developed.

For the Mobile Collaboration (Sun and Jiang, 2008) – situation on which a face to face follow-up is not possible and the communication is achieved by a computer supported collaborative manufacturing (CSCM) system that allows to reduce the huge distances by the communication in a space across computer networks – it is proposed a method for tracking the online work-piece machining procedure with the possibility of tracking of the machining information and machining quality a mobile collaborative environment.

Questions related to mass customization and product catalogue on web service (Ma et al., 2008) when connected to product development is highlighted when speaking about the online product customization. It is proposed a web service-oriented approach, such that users can add competitive offers and generate feature-based CAD models from different vendors over the Internet. The key technique is to create feature mark-up descriptions for the requested library elements. The approach reinforces current un-parameterized and platform-dependent electronic catalogues by avoiding well known hard coding of catalogues within specific CAD systems, and, due to this, makes easier the updating of databases.

Referring to design problems that presents uncontrollable variations in their design parameters, it is proposed an integrated and optimized product design framework (Öztürk et al., 2006) to support the design optimization applications in CE. The effectiveness of hybrid approaches achieved is significant. The proposal considers the use of neural networks (NNs) and genetic algorithm (GA) with integration on design activities. With this, it is used the Taguchi's method and GA for design parameters optimization. In order to keep a data-exchange specification (Kulvatunyou et al., 2008) coherent when it evolves in time, it is proposed a model for the creation, test, and maintenance of a common/shared semantic model that is coherent and supports scalable standards-based enterprise integration. It is considered the development of supporting tools using XML (Extensible Markup Language).

As considered before, CE encourages the development of all aspects of a product life cycle still in design phase in concurrently way inside the multidisciplinary teams which each member has to assure the application of the valid design rules (Greef et al., 1995) of own area. Those design rules are from Total Quality Management (TQM), Design for Manufacture and Assembly (DFMA), Continuous Process Improvement (CPI) and Quality Function Deployment (QFD) being also originated from sources like tables in manuals, equations in text books and heuristic rules from team members experience and expertise. To handle with several design rules, it is proposed a logic-based support system – SPARK - for designers inside the concurrent engineering environment in which design rules are represented as constraints in a constraint satisfaction problem. The solution to this problem is determined through interactive constraint satisfaction performed by a deduction system and associated proof strategy - a feasible design satisfying diverse manufacturing conditions. It is important that the results of such support systems are obtained through a traceable mathematical proof procedure, not derived in an ad-hoc fashion.

Also important is the effect of the Learning Process in Concurrent Engineering Projects (Kara and Kayis, 2005), which can be evaluated using a simulation model - Arena Simulation package - used to test five well-known learning theories through an extensive amount of data gathered from an industry-based project. This is related to two points: concurrency and multifunctional integration. Concurrency is related to reducing product development time by maximizing the level of overlapped and parallel activities in a project. Multifunctional integration refers to functional integration by considering all elements of the product life cycle and the associated design considerations during the earlier design phases.

Focusing on concurrency, this affects the planning of the product development project and its execution on which requires careful planning and execution of complex, interdependent tasks simultaneously due to the complex precedence relations involved. If not, it may lead to increased iterations resulting on increasing the project completion time. The number of iterations largely depends on uncertainties in the process and learning occurs during the subsequent iterations. By other side, the number of iterations will be progressively reduced as CE team members gain a better understanding of each activity – learning. Focusing on the learning process during may allow project managers to predetermine the number of iterations to minimize possible delays in original project completion time. Back to the simulation model mentioned above, the results suggest that all the learning models show similar behaviour in terms of number of iterations required for the ultimate learning once their maximum value is reached.

5. CONSIDERATIONS ABOUT THE TOOLS APPLIED IN CONCURRENT ENGINEERING

Starting with Quality Function Deployment (QFD), this tool supports the presentation (Duhovnik et al., 2006) of processes (description) that allow recognition of suitable natural systems (essential environmental influences) and their transformation into technical systems and a model for management of development process. The phases of quality functions deployment (QFD) during the new product development process along with the location for collecting customer needs and wishes are presented. A detailed description is given on information resources for obtaining data on customer needs; the methods for obtaining, structuring, and evaluation of the data obtained. At the end it is presented a study case to exemplify what is shown. All of this in order to allow the company achieves shorter product development time, lower costs, high quality of the product, and finally, customer satisfaction, always considering the customer requirements and needs during the new-product-development process.

Another aspect about QFD (Zhaoling et al., 2007) refers to the use fuzzy linear programming model (FLP) in order to determinate the target values of engineering characteristics – by QFD: the customer needs results in design requirements, also known as engineering characteristics - which is a complex decision process due to variables and multiple objectives that should trade off, and optimize all kinds of conflicts and constraints. The triangular fuzzy numbers represents all the relationships and correlations, following by the functional relationships between the customer needs and engineering characteristics and, finally, the functional correlations among the engineering characteristics that are defined by the information in the house of quality (HoQ) fully used. The goal by using fuzzy linear programming (FLP) model is to achieve the optimal target values of the engineering characteristics to maximize the customer satisfaction.

Using the Design Structure Matrix (DSM) integrated on an algorithm (Tang et al., 2000) developed for detection of the coupled activities during the design process is important due to the importance within the product design process that is an agglomeration of design activities. Those activities can be classified as uncoupled relationship, coupled relationship and decoupled relationship – always referring to interdependency relationships. The uncoupled relationship means that a design activity is independent from one another (low interdependency between both) with not relevant information exchange between them with activities running in parallel. The coupled relationship refers to that the decision taken in one activity affects one or more activities, and vice versa (high interdependency) with relevant information exchange causing many iteration loops to establish all design information in a proper/robust condition. Finally decoupled relationship are connected to the decisions of early design activities affect following activities, but without any harm, establishing a sequence of decisions that results in a straightforward process without any iteration. The function of the DSM is to show the interdependency relationship between activities allied with a directed graph for illustration of the precedence relationships among design activities.

6. IMPORTANT ISSUES REGARDING CONCURRENT ENGINEERING

As referred initially concurrent engineering is related to product life cycle, from conception to disposal, not only between company and customer but also with the suppliers nominated for the purchased parts. Purchased parts are not only single parts but also sub-assemblies which are not planned for its execution inside the company. Normally the suppliers are nominated by purchaser from a list of approved suppliers, after analysis of the submitted quotation - referring to the manufacturing/delivering of the parts. The quotation prepared is based on available documentation – 3D files, 2D drawings, norms, project quantities and time schedule. At first sight, the goal is to obtain parts according to specification in quantity enough and delivered in time to attend the orders of product manufacturing, but, for this, it is necessary to confirm the feasibility of supplier manufacturing process. That means: Parts are stable in terms of manufacturing and, also, dimension.

First of all, it is required to be available detailed/complete/matured specification design in the first moments of the project, especially for supplier's quotation in order to know exactly the means would be required – equipments and human resources and to allow having a more confident advanced feasibility study. There are several procedures/tools to achieve a matured specification in earliest project stages. For example the DFMA: DFA/DFM should consider three points: (1) to discuss with the potential suppliers, evaluating advantages and disadvantages using supplier's expertise; technical knowledge; quality system and logistics (2) the repetition of DFA/DFM after supplier nomination (3) the repetition of DFA/DFM in advanced moment inside the project in order to close the open items. Other tools like Design for Six Sigma, used in order to obtain a more robust design, shall be considered and, in case of valuable results, be integrated in DFA/DFM current tools. A robust design helps to get this desired dimensional/appearance stability in manufacturing process of the supplier.

The mentioned supplier stability (also "feasibility commitment") can be used to support the elimination of the incoming inspection in the company – achieving reduction of costs and possibly the implementation of Kanban / Milk run – focus to a lean production. To implement lean production, we have to consider the "Value Stream Mapping" and "Scaling" of the whole project, considering supplier -> company -> supplier chain in order to implement the just-in-time strategy. There are situations on which VSM is realized together with the DFA/DFM. Considering a "lean philosophy", aspects like supplier location, agreement referring to purchased parts package (one way or returnable package) are important. When data is referred to the type of packing, quantity of parts involved and the type of packing are important items during the design of manufacturing process of the company. An example of this is the need of re-packing inside the company, causing more costs to be considered. Continuing on the "lean philosophy" we can orientate the integration of individual parts, generating "sub-assemblies" to be delivered by the suppliers making easier the manufacturing process inside the company.

Also during the DFMA and VSM, conceptual ideas as standardization, *poka-yokes* and *Jidokas* should be considered for parts design / tool projects, predicting the possibility of reinforcement/ readjustment in case not 100% functioning. Also the purchased subassembly shall have proper mechanical drawings referring the mechanical drawing index of individual parts and key dimensions of individual parts that shall be considered valid in sub-assembly status. Other issues to be considered regarding mechanical drawings are as follow: (1) to issue a "universal" specification for common understanding between the company and suppliers. For example: elaborate specifications using the GDT (Geometric Dimensional tolerance), (2) to consider "envelope criteria" as indicated in public norm ISO 8015 (3) to define the tolerance range for application in general dimensions (4) also for dimensions taken from 3D files (5) to consider a linear dimension for the Statistical Process Control (SPC) on supplier (6) to update the drawings and 3D files in order to record real values obtained in the real parts with the intention to have always the accurate design. It is important in case of duplication of the tools or the choice of second source.

The indication of the index of all public norms, customer standards used for first parts validation/approval, assists the definition of the design freeze. In terms of parts measurement it is important to achieve agreement between the company and the supplier. The use of the GDT or envelope criteria helps in the standardization. In other cases, the indication of measurement positions, indication of the measurement equipment to be used, or establishing that measurement shall be performed with the use of specific fixture/jig – measurement using CMM or even a caliper. The supplier shall have in mind that the choice of the measurement equipments shall assure repeatability and reproducibility (R&R) and that the use different measurement equipments shall be validated before. Going back to the use of jigs shall be indicated in the mechanical drawings and with existence at company and supplier.

The design of the tools is also important to assure a consequent analysis of the tool project by a company expert, checking if the tool design proposed assure the quantities of project, if the design is compatible for application in other qualified suppliers in case of transference of the project and, again, if the parts obtained can achieve the specification proposed. It makes sense to have a review of the specification – especially 2D drawings and 3D files – during the project of the tools done together with the supplier and company development group. This may last longer as predicted, but it is profitable if the results obtained achieve goals like having robust tools (reduce quantities and extension of corrective maintenances), robust parts and stable processes. It is also important knowing, from the beginning, the keys dimensions, in order to assure that the tools are designed / built in order to manufacture parts that fulfill all of them.

Other point important is related to who is responsible for the project of the tool. Leaving the project of the tool at the hand of the supplier without any verification by any company expert is risky, especially depending on the "maturity" of the supplier to the technology involved. In case of failure on the advanced project stages may represent the project failure. Depending on the problem, there is no available time to correct, modify or, even, build a new one. At last, also giving importance to the fact, the company, especially the worldwide ones, with different divisions with specific products line, shall have nominated officially the steering committee of recognized experts in manufacturing process empowered and with specific tasks of evaluation/validation of the tool projects and to provide guidance when there are evidences that the project shows signs of the risks.

Everything mentioned so far follows a time schedule. The company deals with the project following a Project Management Plan for which the approval of purchased parts is one of the items. There are cases where the supplier nomination, realization of DFA, DFM, QFD are not considered in it. Even the supplier should have their time schedule to monitor the evolution of the project inside house considering the tool project / construction, the development of all manufacturing processes and the consideration of all structural and human elements for completion of the project. Also important is the role of the project leader inside the company. He/she shall have clearance in decisions related to the involved costs, suppliers nomination, discussions with the final customers of points not clear or not feasible, to have the final vote inside the project team to decide the way to go is fundamental for the for the good course of the project.

As noticed, the project at the supplier runs concurrently with the project inside the company. Both time schedules are connected with the items referring to parts delivery, even the sampling. Any delay caused by the supplier causes a delay in time schedule of the final product. In the same way, any delay caused by the company, such as, a late design change, can cause a delay in supplier time schedule which can cause a delay in time schedule of the final product (chain reaction). The acceptance by the supplier of altering the design during this phase shall be properly evaluated, not only in terms of technical/costs situations, but also, referring to deadlines agreed with the company. Probably some of the design changes required can be considered as running after SOP.

All projects have planned a certain number of qualification series using purchased parts in different stages of manufacturing process of the suppliers and/or different concept level. Sampling shall be agreed with the company in order to have parts delivered by supplier in proper time. Products, as purchased parts, are in different mature levels attending the period of time considered in the time schedule. The products once assembled are submitted a qualification, conformity and functional tests. The results are evaluated requiring actions to be implemented together with the supplier or alterations of design. For the success of the project, it is recommended a consequent follow-up on the suppliers by the company using Open Points List (OPL) reporting to the project team all the findings –– highlighting the critical points and propose solutions discussed with the suppliers. Remotes follow-up – in case of suppliers far of the companies - does not assure efficiency or feasibility.

Initially, the goal is to achieve the design freeze in terms of concept in which the final customer is satisfied with the product achieved. Achieving that, the goal changes to finalization of the parts approval process in which the supplier should present evidences of dimensional capability and total feasibility. Depending on the part design or the supplier chosen, the supplier manufacturing process is evaluated by the company by process audit. The realization shall be scheduled when the first parts of the tool are available and manufacturing process achieves mass production status. The parts approval process shall be a mirror of the supplier manufacturing process in which all documents presented transmit detailed information, not only parts dimensioning, but also the supplier quality system applied on. Each company has specific procedure for parts approval with a list of documentation required. All deviations reported and agreement achieved with the company development should be recorded in the mechanical drawings. During mass production it is considered the parts requalification, although the supplier realizes SPC, in order to check the occurrence of an unnoticeable variation on not statically controlled dimension. This is applied on monitoring the tool deterioration in long run projects and, also in cases of, especially, use of carry-over parts in new project.

7. CONCLUSION

The expectations of the final customers, especially the car manufacturers are to have the products in time and with quality. Also, that the companies have flexibility on production to attend the fluctuations in orders to provide more or less quantities, depending on the market. The companies have to prepare the manufacturing lines – adopting lean design – to receive the purchased parts and integrate them, and assemble in order to get the final product. It is important to have purchased parts with a given confidence – dimensionally inside specification and with stability. Purchased parts with defects, that requires selections and reworks, shall be avoided during mass production especially when refers to situations with root causes referring to parts design and / or the supplier manufacturing process that not assures a feasible project. It is not allowed to waste time to check all parts that realize incoming in the company. To have sporadic control, yes, but not 100% of incoming inspection.

There are a lot of subjects to be considered for improvement in whole process, since the effects of the incomplete specification, criteria for supplier nomination (based only the submitted quotation), validation of project of tools, consequent time schedule, consequent follow-up on the supplier, revision of the project (quality assessment gates) and others. As we can see, everything runs concurrently in company and in suppliers and problems have tendency to merge between both, at some moment during project execution. The main focus of this work reveals that concurrent tasks between customers and suppliers cause most of the delays in production and are the basis for further work. Methodologies and tools should be focus of further investigation in order to improve quality issues requirements in order to depict improvements regarding concurrent engineering.

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SIMULTANO INŽENJERSTVO: PREGLED S OSVRTOM NA GLAVNE ZNAČAJKE I ALATE[5]

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Sažetak

Simultano inženjerstvo predstavlja metodu rada koja se temelji na paralelnim zadacima odnosno obavljanju zadataka istovremeno. Odnosi se na pristup koji se koristi u razvoju proizvoda u kojem je funkcija inženjering dizajna, proizvodnje i ostalih integrirana kako bi se smanjilo ukupno vrijeme potrebno za plasiranje novog proizvoda na tržište. Utječe na sve elemente životnog ciklusa proizvoda, od nastanka do opadanja njegova značaja, uključujući i kvalitetu, cijenu, raspored te zahtjeve kupaca. Pojam simultanog inženjerstva je sve sveobuhvatniji stoga bi trebao uključivati suradnju i konsenzus među onima koji su uključeni u razvoj i korištenje računalnih resursa (CAD / CAE / CAM / CAPP / PDM) i metodologije (DFX, QFD, itd.). Cilj ovog rada je prikazati sadašnje stanje znanja i dati nove smjernice za buduća istraživanja u simultanom inženjerstvu s posebnim naglaskom na kupca i zahtjeve procesa, kao i ograničenju vremena i kvalitete.

Ključne riječi: *simultano inženjerstvo (CE), razvoj novog proizvoda (NPD), upravljanje životnim ciklusom proizvoda (PLM), dizajn strukture matrice (DSM), upravljanje lancima dobave (SCM), upravljanje kvalitetom (QFD).*

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