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Research paper

Concurrent Engineering for Uppers Stream Process of Stamping Dies

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Abstract

The new-product development process is very important to manufacturing companies in all the product being developed. The product being developed must meet all internal company processes, customer requirement and to be delivered at the planned time. The modern approach in new product development is concurrent engineering. This paper reviews the concurrent engineering development and practices in several countries and industry. An investigation on concurrent engineering approach to selected manufacturing companies were conducted and analyzed. Concurrent engineering implementation is moderate due to organizational, tools and communication barriers. Secondly, the use of digital tools such as Electronic Data Management/Computer Aided Engineering/Computer Integrated Manufacturing is low. To ensure the success of concurrent engineering for critical process in new product development such as stamping process, the stamped part accuracy and considerable processing timings are the key factors.

Keywords: *New product development; concurrent engineering; stamping simulation management; collaborative design*

1. Introduction

The development process includes designing and building the product into a prototype; creating a defined and configured product design that is tested for product performance against performance requirement; and then planning for production, marketing and distribution [3]. The concurrent engineering is very significance in new product development – address customer needs and satisfaction, produce product data right for manufacturing, better product quality, reliability and cost reduction. Many of the functions and processes to be executed in parallel, and some will be intensify depending on the requirement of product. With the emergence of large multinational corporations from different countries, the market and customer requirements become more complex. Thus, it increases the competition in term of product quality, faster product introduction, product specification advantages and high customers' satisfaction. The paper reviews the concurrent engineering principle and practices in selected industries processes and countries.

2. A Glance of Concurrent Engineering

A number of models exist which propose the sequence of events involved in a systematic approach for product development. Some of these models deal specifically with the design process itself while others take into consideration the whole process of introducing a product, including manufacturing. The steps which are required during the development process are identification of need for the product, development of a product design specification, generation and evaluation of design concept, detailed design of the most promising concepts, design and development of the manufacturing facility and distribution and sale of the new product [32].
There are two approaches in implementing the concurrent engineering, i.e. the team-based and the computer-based approach [10]. The team-based comprises expertise from different functional areas such as design, engineering, manufacturing, production and marketing. The team reviews the product design i.e. clay model or rapid prototyping model and identify possible functionalities and process issues that may arise from the initial design. The product design will be harmonized accordingly to prevent major product changes at later stages in product development stages.
In the second approach, the product designer able to release a preliminary CAD data at early project stage. At this stage, the computer aided applications can be used as a tool in integrating the pre-released CAD data with process planning, formability assessment and assembly assessment as well as material selection.
The success of concurrent engineering depends on four basic elements; people, computer aided application, process expertise, engineering management tools and organisational type [14]. The first and last elements are people, and computer aided application in the fast pace technological key enabler and the fourth is engineering management tools, which are:

1. Quality Function Deployment (QFD)
2. Advance Product and Quality Planning (APQP)
3. Total Quality Management (TQM)
4. Design for Manufacturing/Design for Assembly (DFM/DFA)
5. Failure mode and Effect Analysis (FMEA)
6. Risk Management
7. Lean Manufacturing
8. Basic and advanced seven tools of quality
9. Value Engineering

10. Continuous Process Improvement

Many large organizations claimed the benefits of implementing the concurrent engineering in product development cycle. The benefits are products that match precisely customer needs, shorter time to market, earlier breakeven point, fewer late changes in the program that reduce cost of development, simpler and cheaper manufacturing processes, assured quality from product, low service cost through the life of the product and less risk of failure [18].

3. Methodology

The paper discusses the evolution of concurrent engineering since the 1980s due to high utilization of computer technology that enable companies to make radical changes in new product developments philosophy and methodology to remain competitive. The investigation were made to several countries and companies that opted concurrent approach in developing new product. The details of implementation of automotive industrial practices were discussed in the development of new stamping dies for Malaysia automotive industry. Then, the implementations of concurrent engineering in selected countries are evaluated to identify the barriers in fully implementing concurrent engineering tools.

4. Principles in Concurrent Engineering

In the 1980s, companies started to feel the influence of large multinational organizations on markets, increased product complexities and new developments in innovative technologies. This directly affected the organization's ability to develop and introduce the new products to the marketing [27].
With a large number of multinational companies competing in the world market, thus, it increases the completion level. Each company is competing in various aspects such as shorter product launching, better quality product, specification and features, product services and customers focus orientation. The competitiveness of US firms in the 21st century global economy depend on their ability to develop and deliver innovative products and services [2]. This reality has led firms to search ways to improve their new product development efficiency (e.g. reduced cost, faster time-to-market) and effectiveness (e.g., higher new product quality, greater market success) [5]. Other than condensed competition factor, the major developments in information technologies have taken place in 1980. Among the output of information tools are electronic communication tool and computer aided application tools, namely, computer aided design (CAD), computer aided manufacturing (CAM) and such other tools in planning and marketing areas [32].
Concurrent engineering is a management and engineering philosophy for improving quality, reducing costs and lead-time, from product conception to product development for new products and product enhancement. The concurrent engineering covers all steps from scratch, concept to customer services and being performed simultaneously or overlapping. The execution of concurrent engineering process can be attained through the use of multidisciplinary team and key principles [12].
The key principles to implement concurrent engineering according to [23] are as follows.

1. Employ multidisciplinary product design teams, consisting of a member from each department with a stake in the product, to work together on the design, each contributing their own area of expertise and knowledge to improve the design process. The purpose of the team is to conceptualize the product and optimize it until a consensus agreement is reached on functionality, produce ability, reliability and the cost of the product.
2. Improve the communication with current and potential customers. Translate the customer needs into specific product specifications, quality, process, function and aesthetic requirements, etc.
3. Design the manufacturing and the required processes simultaneously,
4. Involve suppliers and subcontractors at an early stage of the design.
5. Create a three-dimensional/solid (CAD) model of your design.
6. Integrate your CAD/CAM and analysis tools.
7. Simulate product performance and the manufacturing processes as early as possible.
8. Use structured techniques to enhance product quality and reliability.
9. Use quality techniques to understand the role and integration of product and process parameters.
10. Incorporate the lessons learnt from previous products in a new design.
11. Continuously streamline the integrated design and manufacturing processes.

The information-type view in developing new product have been adopted in concurrent engineering background [4], [7]. One way to improve new product development outcome is to utilize information technology tools [20], [26]. For example, to obtain higher new product quality, an intense use of computer aided application software such as finite elements software at the early product design stage. Upon completion of initial release 3D part data, the appointed concurrent engineering engineers equipped with simulation/finite element software starts to review and propose changes based on the design rules and heuristic approach. The changes and review are recorded as engineering changes.
Engineering changes involve the modification of products and components that occur after the part design is released [4], [13], [30]. Development processes for complex products usually involve many engineering changes, which mostly reflect technological advances, resolve defects in the design, and improve the overall quality of the products [1], [21]. Engineering changes are considered inevitable, especially for complex products, because product development usually takes longer time and involves large teams including designers and engineers who are often geographically and departmentally distributed.
To avoid major changes at downstream activities, manufacturing companies have to adopt new technology based strategies. As far as manufacturing automotive sheet metal parts are concerned, strategies and technologies still need to be developed to reduce die-manufacturing costs and to shorten lead-time related to the product development. Application of finite elements for deep drawing and stamping analysis to achieve less problematic die designs, the workable tools and efficient forming process at mass production. Finite element simulation is therefore received increasing attention within the industry [9].
The conventional sequential approach suggests that all developments process from styling to the mass production is executed in single flow direction. Any feedback and improvement at die try-out need to be routed to prior process (Die manufacturing, Die Design, Process design) before it reaches part design. The possibility to miss out the tracking of significance feedback and improvement are higher. The development of a new sheet metal product in the sequential approach is shown in Figure 1.

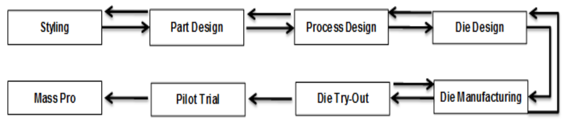


Fig. 1: A sequential approach of sheet metal part development.

While, in Figure 2, the model proposes the new approach in executing the concurrent engineering work. The relevance feedback and improvement in any development processes are stored in a central system. Therefore, respective team members are able to analyse and conduct countermeasure on the raised issues. Furthermore, the data such as cad data, process planning sheet, tooling data and lesson-learned documents can be used and stored digitally for future projects baseline.

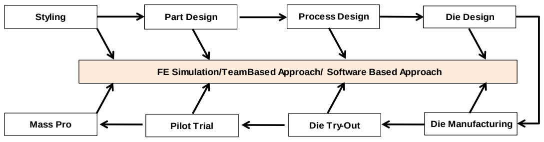


Fig. 2: A Team based and Software based approach

5. Practices in Concurrent Engineering

In Malaysia, the study of concurrent engineering starts in early 2000. A survey was conducted to evaluate the level of concurrent engineering practices in Malaysian manufacturing companies. The survey shows 77.27% of the companies have practiced the multi-functional team; 68.18 % of companies provide adequate training and motivation to the product development team (PDT); 81.82% of the companies had a communication path between all aspects of the project management and the system requirement. The research work from [25] has identified weaknesses in Malaysia's industry:

1. Lack of intellectual properties awareness
2. Lack of research and development (R&D) efforts
3. Lack of understanding on the importance of design for manufacture or concurrent engineering.

[25] has suggested the solution to overcome the above weaknesses. However, a lot of efforts need to be done in promoting the concurrent engineering among the manufacturing companies in Malaysia. The companies must hire local engineers to be trained and participated in product development activities. This pool of engineers must be matched with the expatriate engineers who have longer been working experience in the same expertise area. The barrier of communication must be overcome as the retired engineers are not fluent in the international communication medium, English. The Malaysia engineers must be equipped with the basic knowledge of technical language. The critical expertise areas, to name a few, part design, stamping die design and try-out, Assembly Jig Design and try out and mould design and try-out.
Therefore, it becomes the priority to develop an expert system to mitigate the expertise issues in Malaysia's engineering development. The works will be specifically to develop an expert system in Die-face engineering or formability engineering.
The research conducted in Poland has surveyed four manufacturing companies in a period from 2003 to 2004. The survey work conducted by [15] covers elements of the team based approached, computer-aided application, engineering management tools and execution level. The results of that research work are shown in Table 1.
The survey revealed the knowledge of the concurrent engineering concept such as the team based working is generally good for managers of the department towards to production process preparation. The information tools helped the team participants in preparing the virtual model and communication with customers. The virtual model is the common feature for all companies to produce physical models of product as requested by customers. In Poland, the identified barriers in implementing concurrent engineering are:

1. Communication barriers – lack of collaboration within teams and empowerment within teams
2. Technological barriers – lack of finances

Table 1: Comparison of Concurrent Engineering Implementation

Company/ Activity		**Features of Concurrent Engineering**			
		Team based working	IT	Supporting tools	Concurrent product design
A	Production of equipment to measure water flow	Yes (virtual and conventional team)	Yes	Yes	Yes (partly)
B	Production of parts and element for motor industry	Yes (virtual and conventional team)	Yes	Yes	Yes (partly)
C	Production of cardboard boxes	Yes (virtual and conventional team)	Yes	Yes	Yes (partly)
D	Production of AGD equipment and parts and elements for motor industry	Yes (virtual and conventional team)	Yes	Yes	Yes (partly)

In South Africa, the selected sector for concurrent engineering is automotive supplier industry. The government has boosted the automotive industry by introducing the Motor Industry Development Program (MIDP) in 1995. The study conducted by [19] focused on people and structure, tools for implementing concurrent engineering and involvement between OEMs and suppliers
The responded companies were categorized into company size, company age and company export numbers. In the company's size categories, major companies did not use e-procurement as they prefer conventional methods (e-mail, CD exchange, FTP, others), high cost of software purchase and high software maintenance cost. The smaller companies responded that they were actively engaged in R&D, but larger companies tended to be ambivalent.
In company age category, the companies that have been in operation for more than 30 years answered neutral with regard to their company systems, and processes facilitated internal and external communication. However, the younger companies felt that their systems and processes facilitated effective communication internally and externally. Both types of companies generally re-invest their earnings to improve their facilities and processes.
Looking at export number category, companies, which export more than 40% of their component, show high involvement with OEMs companies or partner companies. The companies sent employees to these companies to facilitate the transfer of knowledge. South African automotive suppliers have responded that an applicable method must be set up to improve the inter-firm communication of information, especially during the procurement process. The methods must be able to keep track of data, process simplification, produce right costing and the level of quality achieved.
The quantitative information about the concurrent engineering effectiveness in British industry is investigated by [31]. The companies involved in the survey are divided into two sub-groupings – LSEs (Large scale enterprise) and SMEs (Small to medium sized enterprises).The questionnaire covered three main areas:

1. The present status of concurrent engineering applied to new product development
2. The perceived barriers to the adaptation of concurrent engineering
3. The use of concurrent engineering tools and techniques

The survey has shown that the companies are actively involved in concurrent engineering, which 65% of SME and 50% of LSE given such feedback. On average, both types of industries have good organizational structure and communication infrastructure. However, the large companies (LSEs) have better defined new-product development procedures and requirement gathering, as compared to SMEs. For SMEs, they depend on the LSEs companies to define the products they produce. Good development procedures guide the SMEs companies to produce the products to meet the stringent quality and delivery demand.
Lack of management training is seen as the number-one barrier. The participants perceived concurrent engineering as a new tool and different way of working that requires the learning of modern practices and skills. Subsequently, the next most noticeable barri-

ers are to understand the use of new concurrent engineering tools and promotion of these tools to the vendors.

The most significant finding under this area is the low implementation of fully integrated Electronic Data Management/Computer Aided Design/Computer Integrated Manufacturing system, which employs the following techniques:

- Integrated product specifications
- Integrated product data
- Online documentation
- Open architecture systems

On the other side, there are four concurrent engineering techniques were rated good of better by 60% of both groups:

- Design for manufacture and assembly
- Integrated product data
- Design reviews
- CAD

The surveys have indicated the barriers in implementing concurrent engineering in British industry is communication and methodology problems in collecting, organizing and controlling the data which defines the features and operating parameters of new products. These findings are confirmed by [24].

6. Collaborative Scope of Work

[28] has proposed an overall architecture of collaborative design environment for metal stampings that incorporates three agent communities: part design agent (PDA), die-maker involvement agent (DIA) and coordination agent (CIA). Each agent community has facilitator which provides an intermediary between a local collection of sub-agents and remote agents through two main services: routing outgoing messages to the appropriate destinations and translating incoming messages for consumption by its agents. The PDA includes such sub-agents; material selection, concept design, feature-based design, and product modelling. The DIA contains three sub-agents: part formability evolution, cost analysis, and process planning. The CIA just like a project moderator is to monitor and coordinate other agents to render consistency to their decisions. Through task coordination and conflicts management, the CIA aims at enabling better collaboration and design-decision consistency among, different parties concerned namely product designer and die-maker involved in new product development process.

In the industrial practices, the die-maker involvement agent is under Engineering section which responsible on Die-Shop production, tooling procurement and Quality control-related activities. The responsibility matrix for Die-shop production, tooling procurement and Quality control is organized in the following format and responsibility. The responsibility matrix is restricted to the concurrent engineering work related only Table 2.

The main output of concurrent engineering activities for Die shop and Quality control is to issue product improvement feedback via Product Change Request (PCR) format. The product designer examines the PCR feedback and incorporates the changes into the 3D part data. However, there are many occasions where the PCR is rejected by product designer. The rejected PCR is usually proposing the part shape changes that involve other processes such as part matching for Body Assembly and part fitting for Trim and Final. The unaccepted changes definitely produce negative impact to stamping part production and stamping part quality.

Table 2: Responsibility matrix for die-shop parts

Main Work Item		Sub Work Item & Descriptions	Collaboration		
			R&D	PE	QC
1)	Clay model Review	Clay model Review based on Formability, Productivity and Quality.	I	R	R
2)	Drawings Check	Drawing Checking Items: Formability, Tension, Dent-ability, Boundary, Parting Line, Yield Ratio Improvement, Productivity Upgrade (Workability, Safety and SPH) and Study of dies cost reduction (Process minimizing and Double Parts Dies). Matching activity for Body Assembly	I	R	I
1)	Budget	Budget Establishment for itemized cost		R	
		Application for budget, approval for budget		R	
2)	Package Proposal	Tender Package Proposal [Classification for each groups]	I	R	
3)	RFQs Issue	Prepare RFQs for in-house & vendor dies		R	
	Place Order				R
4)	Evaluation & Report	Evaluation and Study report [Technical Matter], including Clarification meeting.	I	R	I
1)	Soft Tooling	Follow up whether problems discovered at SE work, should be modified or not. And follow up whether it is possible to change design in terms of dies structure or not.	R		
2)	Proto	Check and follow up for problems discovered at drawing check by using white body based on item by item.	I	R	

7. Die Face Design

It is a good practice to perform the concurrent engineering work for stamping parts at the earliest possible time to select the optimal shape for formability. For die-production, the concurrent engineering depends strongly on how finite element simulation is utilised to the design and analysis of the process, the tools and the part.

The types of finite element algorithms and procedures are:

1. Incremental Implicit
2. Explicit FE Methods
3. Dynamic Explicit FE Schemes
4. One-step deformation theory

On the application side, DYNAFORM utilize explicit finite element codes; ABAQUS uses the implicit and explicit finite element codes; and AUTOFORM uses one-step deformation theory. The selection of finite elements codes are depended on the required accuracy of various parts involved in calculation. As an example, the easy construction parts can be simulated by one-step theory software while the complex-construction parts employ Explicit and Dynamic finite methods/software. By applying the right finite-element software, the stamping parts flaws can be predicted and improved at product design stage rather to wait for the feedback from Die try-out feedback. The stamping parts flaws are cracks, necking, wrinkle, and dimensional spring back. There are tremendous of studies to eliminate or to control the dimensional spring back issues. Meanwhile, the study focuses on another type of stamping parts flaw is minimal.

Wrinkling is the undesired surface defect for functional or aesthetic reasons. Wrinkling can be caused by extra metal flow that being pulled by adjacent wall material flow, non-uniform stretch, shear deformation or compression due to material deviation.

The detection of stamping parts flaws begin with the creation of Die-face. The die-face design for a sheet metal forming die may be defined as the composition of a complete surface geometry that deforms a sheet metal blank plastically into a desired stamping shape by ensuring a rigid tooling construction. The design process starts with the part geometry as the basic input data. The engineer decides on the drawing direction by tipping the part to the most favourable axis, and eliminating the risk of an undercut. Then, using the material formability and minimum allowable thickness, the amount of stretching deformations is determined and the number of stretch-draw operations is estimated. Using the half-thickness offset geometry of the sheet metal part, the engineer sets additional surfaces for the punch face by extending the part edges, filleting the sharp edges and unfolding the flange-type of geometry in the CAD environment. Using the material properties and the amount of maximums stretching deformation, the maximum achievable drawing depth is estimated, and a set of drawbar and counter bar surfaces may be added to both punch and die in order to the deformation gradient during the initial stage of the forming process. After deciding on the press operation type, the binder geometry is generated using a set of flat or developable surfaces, and usually integrating with the draw-bead and contra-bead elements in order to restraint the material. However the punch is controlled in a designated manner [8].

Before performing the finite-element simulation, the parameters such as material parameters, allowable thinning of the part, the blank side and die modelling surface must be confirmed. The finite-element simulation of the stamping process is executed in two steps.

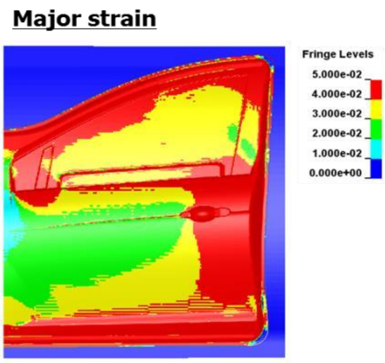
A forming analysis is conducted to determine the metal deformation for a given punch and binder loading and, secondly, the spring back deformations following the removal of the tooling is computed with the forming stress distribution and the deformed geometry from the forming step as the inputs along with material thickness distributions.

Depending on the relative qualities of the process and material parameters, several virtual try-outs may be necessary in order to reach the optimum tooling geometry and forming elements such as cracks, necking or wrinkles.

At this point, the forming loads and the type of draw action is determined in accordance with the available press line specifications [6]. Any defects have been detected at this stage, the engineer will fill-up the PCR document and specify the details of flaws. Subsequently, the completed PCR will be evaluated by other die team members and propose for the best solutions to product designer.

8. Industrial Case: Front Door Outer

The industrial case has shown the results of surface deformation at die-face engineering and actual production stage. When engineers evaluated sheet metal that had been deformed through simulation, areas of high strain were observed to be in the near failure or red zone (negative safety margin). The areas are critical but did not fail according to major strain and minor strain analyses, Forming Limit Diagram. At the same time simulation engineers and die try out staffs to attest that the entire stamping was in green zone condition or safe. The simulated part is Door outer and the simulation analysis is indicated in Figure 3.



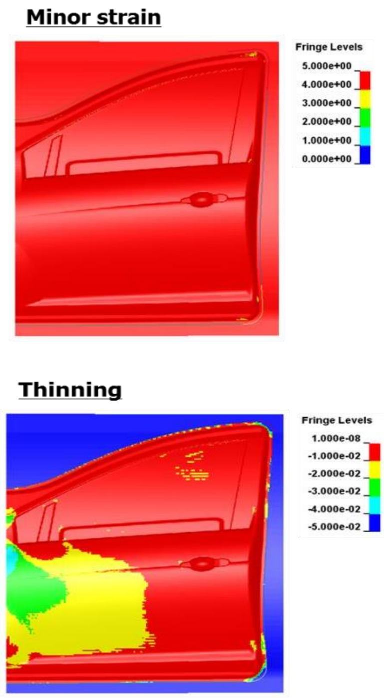


Fig. 3: Surface Deformation Results at Concurrent Engineering stage (Explicit Software)

However, the actual quality control procedures at actual production stage have detected the stamping flaws at certain areas, particularly; door handles area. The simulation results is indicated the flaw is indicated in Figure 4.

The researchers have focused on the combination of FE-analysis and optimization technology to optimize stamping process and produce the desired part quality. [17] has proposed an optimization method to improve the formability of automotive side panels. While, [16] optimized the die shape to improve forming defects, such as fracture and wrinkle, in a two-stage deep drawing process.

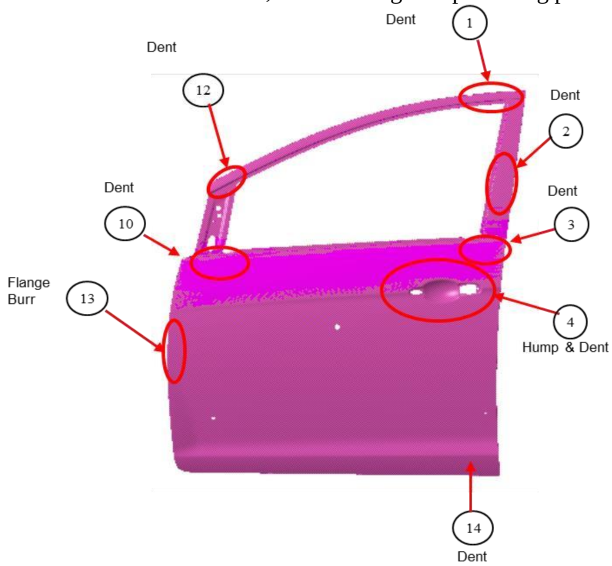


Fig. 4: Surface Deformation Results at actual Production stage

The forming analyses of sheet metals are performed repeatedly in the design feasibility studies of production tooling and stamping dies [29]. With these analyses, the formability of the sheet metal part can be predicted and possible to detect deformed geometry of stamped parts as indicated in Table 3.

Table 3: Monitoring of results on surface deformation

Trial No		#1	#2	#3	#4	#5	#6	Note
1	Dent	Bad	Bad	Bad	Ac-cept	Ac-cept	Ac-cept	
2	Dent	OK	OK	Bad	Bad	Ac-cept	Ac-cept	
3	Dent	Bad	Bad	Bad	Ac-cept	Ac-cept	Ac-cept	
4	Hump & Dent	Bad	Bad	Bad	Bad	Bad	Bad	Re-work
5	-	OK	OK	OK	OK	OK	OK	
6	-	OK	OK	OK	OK	OK	OK	
7	-	OK	OK	OK	OK	OK	OK	
8	-	OK	OK	OK	OK	OK	OK	
9	-	OK	OK	OK	OK	OK	OK	
10	Dent	Bad	Bad	Bad	Ac-cept	Ac-cept	Ac-cept	
11	Hump	OK	OK	OK	OK	OK	OK	
12	Dent	Bad	Bad	Bad	Bad	Bad	Bad	Re-work
13	Flange Burr	OK	OK	Bad	Bad	OK	OK	
14	Dent	-	-	Bad	Ac-cept	OK	OK	

9. Conclusion

Concurrent engineering as engineering management tools is widely accepted by many industries and organizations. The pressures of high market competition, cost-reduction initiatives, and shorter product life-cycle and higher-quality expectation are the main factors in concurrent engineering evolution.

Referring to the implementation of concurrent engineering in British industry, they have a low implementation level by integrating full Electronic Data Management/Computer Aided Design/Computer Integrated Manufacturing system. The possible cause is the high investment cost in setting the information technology platform and the operational set up are tough such as the companies have limited available seats of systems and project team has limited access. Furthermore, the full Electronic Data Management/Computer Aided Design/Computer Integrated Manufacturing system requires intensive data entry for full scale implementation of the system.

The barriers in implementing concurrent engineering are investigated and compared among the selected countries. The finding is communication and methodology problems in collecting, organizing, and controlling the Design data. This Design data must evolve to Product data that produce significant output in the entire new-product development stages.

Furthermore, on the formability study at die-face engineering stage, a substantial investigation of the accuracy of results from both stages is recommended. The product designer should allow flexibility on the engineering changes at formability stages. To perform the formability study, the product data must be converted into formability data where additional surfaces and addendum are added. These calculation processes are time-consuming and certain number of iteration is required.

All in-work information must be accessible to the concurrent engineering team members; the collaboration via open architecture and sharing information via central system will minimize the communication and information sharing barriers. In addition, a self-training media must accompany the developed model and system. The designers of Design data able to grasp relevance feedback through the early collaboration and feedback from respective experienced concurrent engineering team members. The execution of new-product development stages is fully understood by project teams directly and the company's employees indirectly.

On the formability study, finite element processing is very time-consuming and relies on the users' experience in Die-Try out and stamping part production. The proposed expert system will be centralized on accumulation of knowledge, input from user's experience and heuristic approach to predict the stamping part formability.

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