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A generic IDEFO model of an integrated product development in CIM environment based on concurrent engineering

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Abstract:

A generic IDEF0 model of integrated product development for concurrent design of product and process is presented. The complete model consists of twenty four activity diagrams spanning three levels. A corresponding node index and data is included. IDEF0 was found to be a powerful functional modelling technique which minimized the need for elaborate descriptive text and its graphical presentation provided a clear representation of a complex aspect of design and manufacturing.

Introduction

There are six stages in a new product development. It begins with product design specification and followed by conceptual design, prototype and test, detailed design, manufacturing and support system.The first four stages are in the design phase and the last two are in manufacturing phase. The design phase starts with a definition and specification of product requirements.In this stage the market specification or customer's requirement is translated into the product design specification.In the second stage of design the greatest risk lies because decisions affect directly the quality, manufacturability, reliability and cost of the product .The detailed design begins after components and subsystem, partial prototypes and tested as the need for information arises.In the detailed design stage detailed definition and verification for the manufacture of the part is produced.In the manufacturing stage design data is transfered to manufacturing data and instruction and finished product.In the support stage , customer is provided with service of the product and maintenance. In the traditional product development problems can not be discovered as early as possible , and design changes means going through the cycle from design to manufacture again, which significantly affect the cost , lead time and time to market.Computer Integrated Manufacturing (CIM) has been discussed in the litreture from different approaches Khorami (1991), Ford et al (1990), Panayotti (1992) .CIM has been established as an essential prerequisite in the drive for optimum manufacturing performance. In order to achieve the goal of CIM there is essential to use the Integrated Product Development philosophy. Integrated product development has a key role to play in the computer integrated manufacturing system (CIMS) and the extend to which the concurrent engineering principles are applied, will be the major deciding factor of the competitiveness of a nation's industries. However ,full implementation of concurrent engineering is still far from reality Jo et at (1993)

Integrated Product Development

Integrated Product Development can be defined as the integration of both the product and the manufacturing design processes . This is best assured by having the designers work in manufacturing models,rendering the freedom to add features to the design or manipulate the process plan itself (Cutkosky and Tenenbaum, (1990) .The goal of integrated product development is to reduce the product development time , to reduce the cost,shorter time to market and to provide a product that better meets the customer's expectations .There are two approaches in implementing the integrated product development practice:1) Team based approach ;2) Computer base approaches. Team base approach is human oriented in that team consists of designers and individuals from all other related functional areas such as manufacturing, marketing, R&D, finance, accounting, purchasing, management,supplier and customer . Team members are selected for their ability to contribute to the design of product and processes in early identification of potential problems and timely initiation of action to avoid a series of costly reworks. Multifunctional team is crucial for effective implementation. Continuously developed computer technologies , in both hardware and software have given team

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members from different departments the ability to work with the same design to evaluate the effects of design attributes. In this context,Numerous papers have reported case studies in which the team based approaches were implemented and significant benefit were realized (Allen, 1990). While the team based approach can be readily implemented and is being widely adopted in industry, some shortcomings appear to arise (O'Grady and Young, 1991): difficulties in effective management of the team, team member's limited knowledge ,and the cost of maintaining a team. As more sophisticated computer tools emerge constantly, the team based approach in which the integrated product development philosophy is woven into the internal logic operations, enabling design justification or optimization with respect to the entire aspects of a product's life cycle. The integrated system that does not require any human intervention may yield significant advantages to reduce the product realization time, increase product quality ,and reduce the cost. In other words, human interface, if required, often introduces errors and inconsistencies, reduces the extent of automation, and increase product development time and cost.(Jo et at 1993).

Expert System

Expert system is a set of computer programmes have emerged of development of Artificial Intelligence. It covers the area of human capability related to problem solving and applying expertise.In the last few years , a number of companies and organizations have become convinced that Expert system can bring many benefits for their organizations. They are aware that some companies have started to use expert systems in their design , manufacturing and productions to improve their lead time , cost , market share and productivity and profits. In every expert system, knowledge is the most important factor; it is consisted of two type. The first type is facts which can be obtained through talking and discussing with experts or by reading of books, Journals and other sources of information available. The second type is heuristic knowledge (rules of thumb), that can be obtained by people or human expert through many years work and experience. Any expert system contains the following elements;1) User Interface which allows the user communicate with the system and represent the problem and looking for the solution.2) Inference Engine which is similar to control structure in the traditional program, it operates and select the relevant knowledge to reach the answer and conclustion. The Forward chaining and Backward chaining are two important model of inference engine .3) Knowledge base : The important tasks of the knowledge engineers are to obtain the knowledge(which is the combination of heuristic rules, facts and models of the real world used by expert to solve and control problems in his or her domain of expertise) and design the means of structuring and representing it in the knowledge base. A central requirement of any successful integrated product development system is an accurate and complete .knowledge base of information encompassing all relevant functions. This has more recently been carried out by physically applying teams of experts to the problem. While this is a significant improvement on the sequential approach, there is strong justification for automating this process. This will make the experts apparently available to the designer on an ongoing basis, allowing the application of expert knowledge continuously and during all stages in the design process. Integrated product development that requires limited human intervention by using computer technology and expert system may yield significant advantages to reduce lead time and cost increase product quality, market share and benefit.

A generic Model of Integrated Product Development

The generic models with its context can lead to thinking about what activities are supposed to be done and what kind of data is required. . This paper describes a generic IDEF0 model in design and manufacturing based on integrated product development.

Activity node listing

A43 Determine concurrent design of product and process
A431 Determine Product Design Specification
A432 Design Concept
A434 Design Detail
A433 Determine Manufacturing Requirement from design
A4331 Determine Manufacturability of design

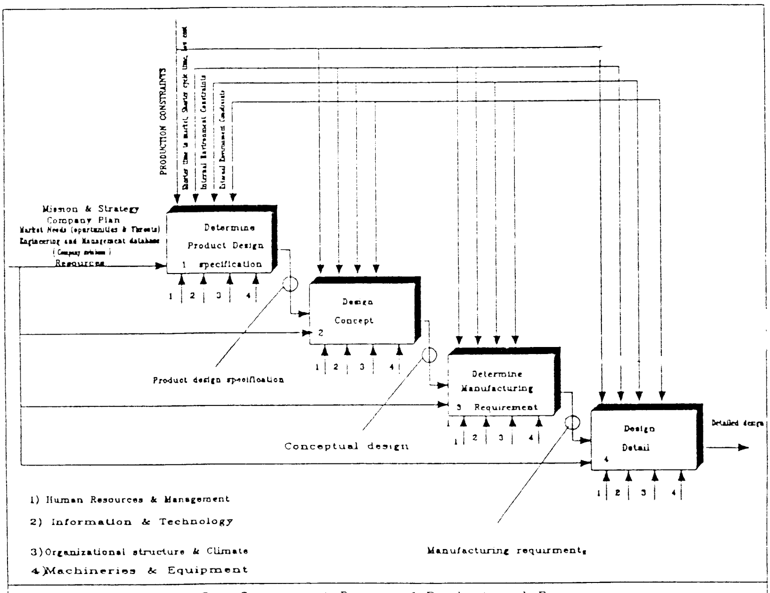
A43311 Select Features from Design Data

Data node list:

D 43 Concurrent design of product and process data
D 431 Specification of product design data
D 434 Detailed design data
D 433 Manufacturing requirement from design data
D 4331 Manufacturability of design data

A43312 Select Material
A43313 Determine Process requirement or capability of process)
A43314 Determine Manufacturability of each feature
A43315 Determine capability of Design for Assembly parts.
A43316 Determine Total Manufacturability of Design .
A4332 Determine Transferability of Design
A43321 Extract Feature from design
A43322 Evaluate Topology of each feature
A43323 Evaluate relational and Identificational data
A43324 Evaluate Tolerances and Surface finish
A43325 Evaluate material and heat treatment
A4333 Determine Minimum Cost.
A43331 Minimize Feature Size and Shape
A43332 Minimize Material (type) Cost.
A43333 Minimize process selection and atool and machining cost.
A43334 Minimize Heat Treatment Cost
A43335 Minimize Assembly Cost
A43336 Minimize Total Cost.

D 3311 Low level information (feature data)
D 43312 Material type and heat treatment data
D 43313 Process capabilities data
D 43314 Data related to each Feature and its required tools, Fixture, and Machineried
D 43315 assembly data
D 43316 Total Manufacturability evaluation data
D 4332 Data related to Transferability of Design
D 43321 Selected Feature data
D 43322 Topology data
D 43323 Data related to Relational and Identificational data
D 43324 Tolerances and Surface finish data
D 43325 Material and Heat treatment data
D 4333 Cost analysis data
D 43331 Data related to minimization of Feature's size and shape
D 43332 Material type data
D 43333 Machine selection cost
D 43334 Heat treatment cost data
D 43335 Assembly cost data
D 43336 Total cost data



A 43 Concurrent Design of Product and Process

A 43 Concurrent design of product and process (Fig. A 43)
Unlike the traditional approach which is sequential and causes many iteration and redesign, the concurrent design of product and process considers simultaneous work between design and process functions.This approach will lead to lower cost, lead time and faster time to market.

A 431 Determine Product Design Specification
The design stage starts with a definition product design specification(PDS) of product requirement.It is translation of market specification or customer's requirement into the required product performance.Other requirements like the base cost of the product, quality and quantitive, standard may also considered at this stage.

A 432 Conceptual design
In the conceptual design , the designer attempts to find the most appropriate combination of mechanical elements and physical phenomena associated with the elements to meet the requirements. .In order to avoid problems found later. all possible situations in which the design

object is used must be considered in the conceptual design. Since the quality of design largely depends on decisions in the conceptual design, intelligent support of conceptual design is strongly desired.

A433 Determine Manufacturing requirement from design data

Today, a major problem of industries is the lack of communication and information flow between engineering and manufacturing personnel. Within many companies these divisions are separate.Design engineers are concerned primarily with ensuring a part meets its functional and market specifications requirements.Manufacturing engineers are left with the task of producing the part as designed, or of negotiating changes in the design when a part can not be manufactured as specified. As a result , many parts undergo a redesign process, which not only results in longer lead times but also increases product costs.Integrated product development refers to the integration of manufacturing knowledge, among other things, into the design process so that the designs obtained will be more cost effective to manufacture.Design and manufacturing have a strong interaction. Design influences the manufacturability of product.Conversely, manufacturing processes may give design constraints. Figure A 433 shows all possible way of challenging designers for Manufacturability, Transferability and Economic of product and process design.

A 434 Detailed design

This is the last stage of design, in which a very large number of small but essential points remain to be decided. The quality of this work must be good, otherwise delay and expense or even failure will be incurred:computers are already reducing the drudgery of this skilled patient work and reducing the chance of errors , and will do so increasingly.

A 4331 Determine Manufacturability of design

This activity involves taking the conceptual design data and engineering data base and then extract designed features. Many noticeable results of DFM practices have been announced.. For instance Jansson et at (1990) described a set of manufacturability indices that can provide a comprehensive definition of manufacturability and be used for evaluating the design early in the design process. Six indices were defined to represent the major aspects of manufacturability, compatibility, bug index, availability, complexity, standardization, and efficiency.(Fig. A4331)

A43311 Select Feature from design

Features closely match the way process planners view the design . Since the most current CAD systems do not store features and their attributes explicitly , a generic approach for automatic feature recognition and extraction is required to make the manufacturing system an integrated continum. Because of the important characteristics that features may contain, several algorithms have been proposed to recognize and extract features from geometric models. .Cunningham and Dixon (1988) explain, however, that different manufacturing processes (Casting, Forging,Metal cutting, Assembly,etc) may require different features for their various activities (Fitting, Manufacturability evaluation, Manufacturing cost analysis, tool/die design and so on).

A43312 Select Material

Selection of material requires a knowledge of the function and service requirements of the product, and the material that are available to fulfil these requirement. It is evident that there are many factors that must be considered in material selection for processing and use (i.e. Mechanical, Physical,Chemical, and Appearance).The relation between material selected for product is a major factor in process selection.

A43313 Select process or (Identify process capability)

In a classical manufacturing system, the integration of machine tools and material handeling system might not be as important as in integrated product development.In general process selection may contain the following activities:

1) Manufacturing equipment selection, 2) Machine cell formation ,3) Machine layout, 4) Cell layout .There are three important issues regarding the manufacturing equipment selection problem Kusiak and Heragu(1988); a) Machine tool selection , b) Material handeling systems , c) Budget consideration. Today , most engineers select a process based on their experience and education.According to individual feature, and component specification , possible machining

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processes are selected.

A 43314 Determine Manufacturability of each feature (process capability)

For each machine or tool used in a process, its machining accuracies such as dimensions,tolerances and surface finishes have to be evaluated to ensure that the machine and tool meet the requirements of the machining process for each feature.

A 43315 Determine capability of assembly

The Assembly of parts or products can be carried out either automatic assembly machinery or manual assembly techniques.The goal of this activity is evaluating design data in term of assembly line , and helping designers to design a product which will be easy to assemble.

A 43316 Determine total Manufacturability of design

This activity refers to total manufacturability of design data , including capability of processes and assembly line based on design feature and material selected material.

A 4332 Determine Transferability of Design

The aim of this activity is to compare design data with related standard data in order to facilitate interchange of drawings and associated data between design and manufacturing . To have true integration of design and manufacturing, it is necessary that design data can be transformed to manufacturing data without human intervention.(Fig. A4332)

A 43321 Extract Feature from design data

This activity select each individual feature from design data , inorder to compare it with the standard feature in the next activity.

A 43322 Evaluate Topology

Topology of an object represent the basic relationship between various elements of the object (faces, edges, and vertices). For example there are nine topological relations between polyhedron components which are necessary to recognize in manufacturing process.

A 43323 Evaluate Relational & Identificational data

This group of data is concerned about a basic relation ship of the two components or entities of an object. For instance whether two elements meet in a concave or convex positionor make 180 degrees with each other. The other description comes under relational is the direction in which a plane is facing. Identificational data'.To reduce uncertainty and ambiguity, every element or feature should be identified. All the planes, edges,vertices,etc. should be individually identified. Initially an entity is given an identity tag , for example 'e' for edges, or 'p' for planes. Since there are so many of these entities , these letters are followed by a number. These numbers usually start from '1' upwards. Then the next step is the identification statement.

A 43324 Evaluate Tolerances and surface finish

Tolerances are important element of a part description. Tolerance control can effect quality as well as cost. Surface finish is concerned about planes or surface tolerances.Tight dimensional and geometric tolerances increase the amount of processing requirement. Specification of tight tolerances also results in the need for more careful measurement of dimensions, frequent regrinding of tools, and use of more expensive equipment.

A 43325 Evaluate Material requirement and heat treatment

This activity refer to checking of high level information related to product design and associate material information with form features. Material information can be of the following types:1) Material name; 2)Material composition code (standard or propritary), 3)Material composition, physical and mechanical properties, 4)Heat treatments to be applied to entire part 5)Surface treatments ,6) Material -process capability)Material -Process compatibility (This category deals with material properties and their relationship with the characteristics of the manufacturing process.

A 4333 Determine Minimum Cost

large portion of the product cost is influenced by product design, it is important to obtain cost estimates as early and quickly as possible during the design phase. In the process of new product design, in order to minimize cost ,designer should be clearly obtained all information related to the following factors 1) Capacity,2) Process ,3) Facility:, 4) People ,

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5) Material , 6) Assembly line.(Fig.A4333) .

A43331 Minimize Feature Size and Shape:

A design problem can be modeled as a sizing optimization model where variables are sizes, such as height, thickness, or radius for a given component geometries and topology of structure.When the shape of boundaries, fillets or holes is allowed to vary for a given topology , a shape optimization model is generated.

A43332 Minimize Material cost

Material cost is the cost of raw materials and depends not only on the type of material, but also on its shape. The raw material may be available in bulk or in the shape produced by casting, extrusion,forging,rolling or drawing with various tolerances and surface finishes.

A4333 Minimize Machining cost

This activity refers to minimization of fixture and tooling cost, machining and material handeling cost.

A43334 Minimize Heat Treatment cost

Frequently, the part requires heat treating at some stage of its production. Heat treating is actually a tool to aid the designer in achieving the goal.This activity looks at the effect of heat treatment cost on design and overall cost of new product development.

A 43335 Minimize Assembly Cost

Assembly is often the most labour intensive operation and accunts for major portion of the total cost. Assembly robots have been used in industry that manufacture simple products in large volumes.The concept of design for assembly(DFA) arises in the hope that all discrete component parts will be designed so that they are easily assembled and the cost is significantly reduced.

A 43336 Minimize total cost

During the design of product, the designer should be aware of the financial implications of the choices being made.The value for a parameters, features,the material, choose of tool and process, heat treatment and assembly cost. They have an influence on the cost of the product. This activity minimize the total cost of a new product.

Conclusion :

Computer Integrated Manufacturing (CIM) has been established as an essential requirement for optimum use of information resources and Manufacturing performance . CIM can not ever become a reality without the use of a certain amount of people, human knowledge, that are effectively used in the organization. The integration of sub-system in a manufacturing organization is not enough. People and more importantly their associated intelligence are needed to optimise the manufacturing capabilities of any organization..In order to achieve true CIM, it is necessary to use integrated product development philosophy.

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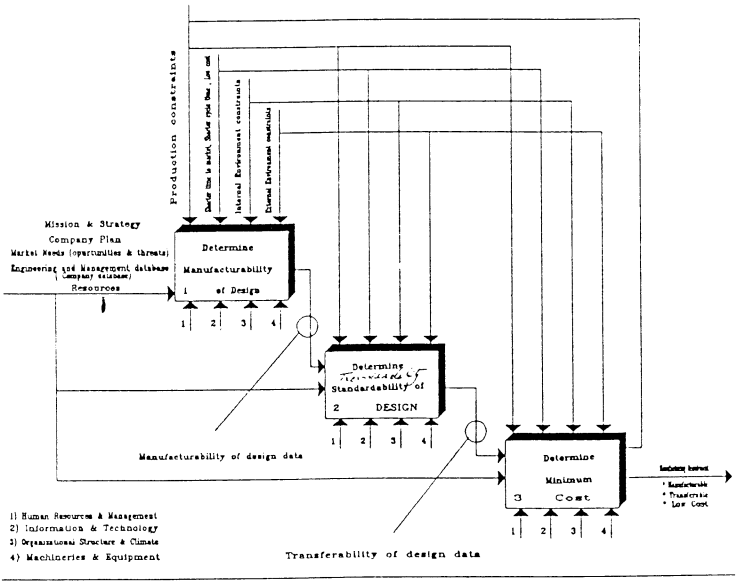
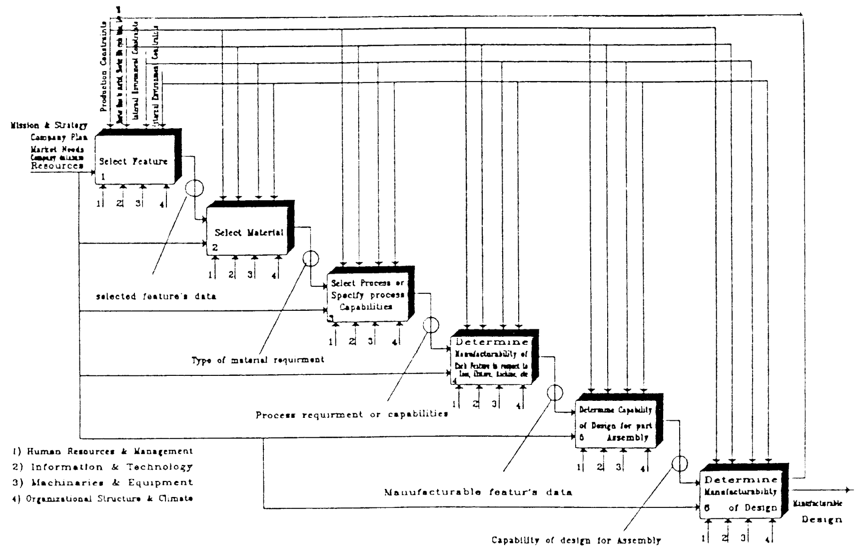


A 433 Determine Manufacturing Requirment



A 4331 Determine Manufacturability of design

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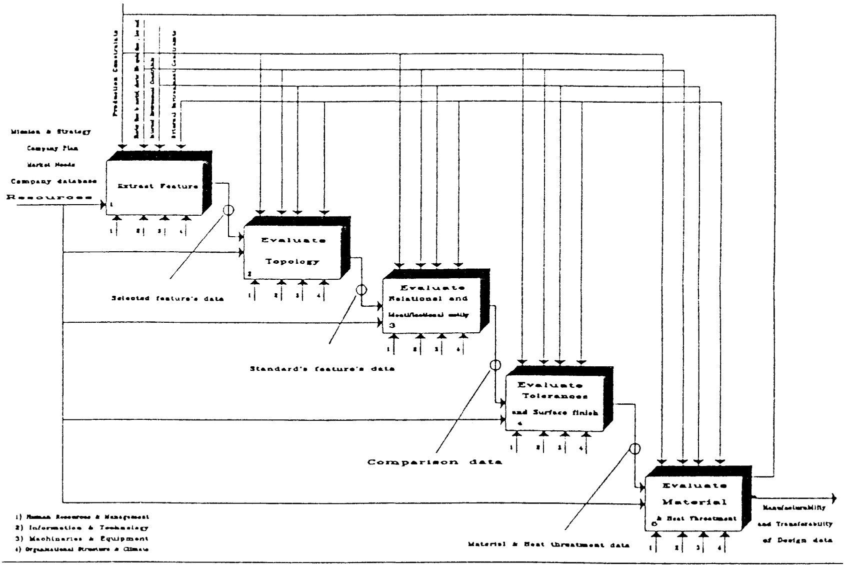
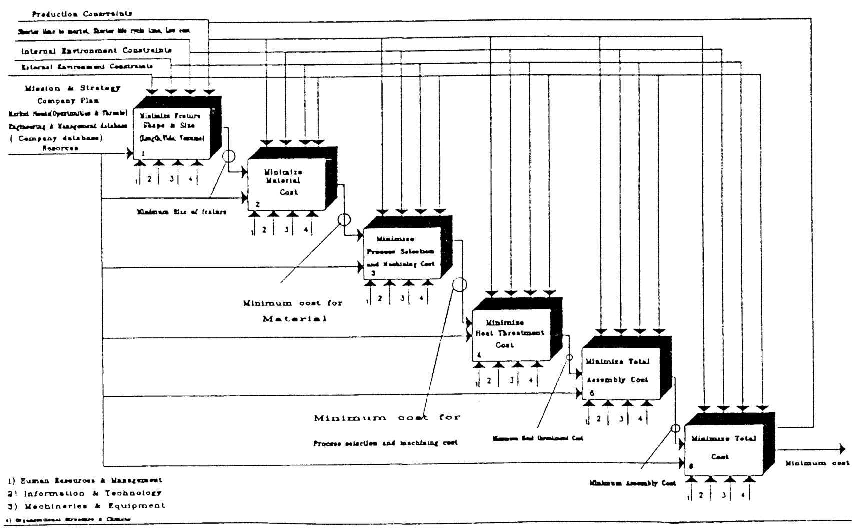


A 4332 Determine Transferability of DESIGN



A 4333 Determine Minimum Cost