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Product Modeling Technology for Computer Aided Concurrent Design

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Abstract

This paper started from problem analysis of existing CAD systems and proposed a set of new features for Computer Aided Concurrent Design (CACD) --- a new generation CAD system. It focuses on concurrent design support, product modeling, design parameters inheritance and information propogating among different hierarchies of an integrated design process. A prototype of a CACD system for plastic encapsulation mold is implemented at Shanghai Jiao Tong University to demonstrate these new features.

Key Words:

CAD, CIMS, Concurrent Design/Concurrent Engineering, Product Modeling

1. INTRODUCTION

Most machine design starts from requirements specification, goes through concept design, detail design and ends up with a new machine product. The design process is, ingeneral, very complex. Figure 1 shows the different phases of a traditional design process. Here, We want make a clear distinguish among a product, an assembly, a sub-assembly and parts. A product is something can perform certain functions that customer demands; like cars for transpotation, machine tools for fabrication and TV sets for entertainment. Product and assembly are terms used interchangeably in this paper. Sub-assembly is one of the components decomposed from an assembly. It can perform certain function that a product needs such as an engine or wheels for a car. Parts are individual components designed to make these sub-assembly and/or product functional. By looking at the cost distribution of different design phases (Figure 2), it is found that most of the design cost was determined in concept design phase (which includes assembly design and decomposing it into sub-assembly, checking assembly conditions and making necessary modifications). But most of the CAD systems today can support parts design only. For rest of the design process such as product performance specification and concept design, they are just not designed for. They are parts oriented rather than products oriented. Due to

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lack of assembly hierarchical information, they cannot associate an assembly with different comoponents and with other assemblies/sub-assemblies in diffenrent hierarchies. Therefore, they can not support the entire process of a product design and concurrent design, which are definitely product orientated [1, 2].

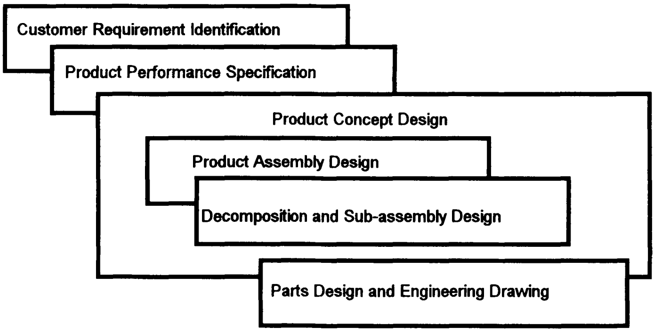


Figure 1 Different Phases of a design process

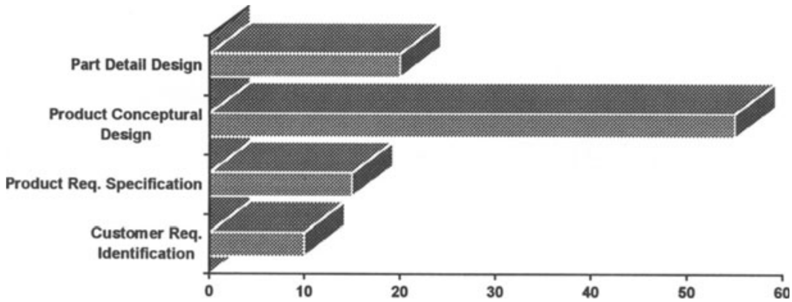


Figure 2 Costs Distribution in Different Design Phases

2. NEW FEATURES OF CACD

Computer Aided Concurrent Design (CACD) proposed in this paper is designed for the integration of entire process of product design. It focuses on concurrent design support, product modeling, design parameters inheritance and information propagating among different hierarchies of an integrated design process.

2.1 Assembly model of in a CACD system

Instead of working on a part model as most CAD systems do today, A CACD system works on a product model -- an assembly model. One of the two major processes of a CACD system is to build a assembly model which could represent the assembly relationship and constrains among different assembly components as well as different assembly hierarchies. Another is to define a set of methods which would enable design parameters and assembly constraints to propagate among different assembly hierarchies. The key here is to construct an appropriate modeling schema to support product modeling, which should be enable us to:

- represent the assembly relationship between components of an assembly or sub-assembly;
- represent the assembly relationship between upper and lower assembly hierarchies;

2.2 Information flow in a CACD system

Keeping a product model unique and consistant during an entire design process is a key factor for concurrent design support. This is important specially when some changes are made during a design process. The propagation effect of these changes has to be considered and handlled correctly to keep the model correct. The design information (the parameters and constraints) of an assembly model is propagated within the CACD system in the following way:

- A concept design is always started from a product in assembly level. According to the original design constrains imposed by customers, a designer can sketch out the whole system and determine design parameters and assembly relationship among sub-assemblies.
- By such assembly relationship, a product can be decomposed into several sub-assemblies and parts. Using the same design parameters and constraints passed from the upper level hierarchy, these sub-assemblies and parts can be designed simultaneously. New design parameters added in these processes will form the design constrains for the next level design activity.
- All design parameters and constrains are the driving parameters of the design process. By simply adjust these parameters a designer could easily modify his design or even make a new design.

3. AN EXAMPLE OF ASSEMBLY MODEL AND INORMATION FLOW

Let's take a shaft assembly design as an example to illustrate the discussion above. Start from the shaft assembly shown in Figure 3a, which is subtracted from its upper hierarchy and has some initial design constrints (Table 1). The designer could then refine the design and add more design information (parameters and constraints) into the initial design (Figure 3b). It is noted in Table 4 that some of those new added design parameters may be related to those initial design parameters according to design rules and constraints.

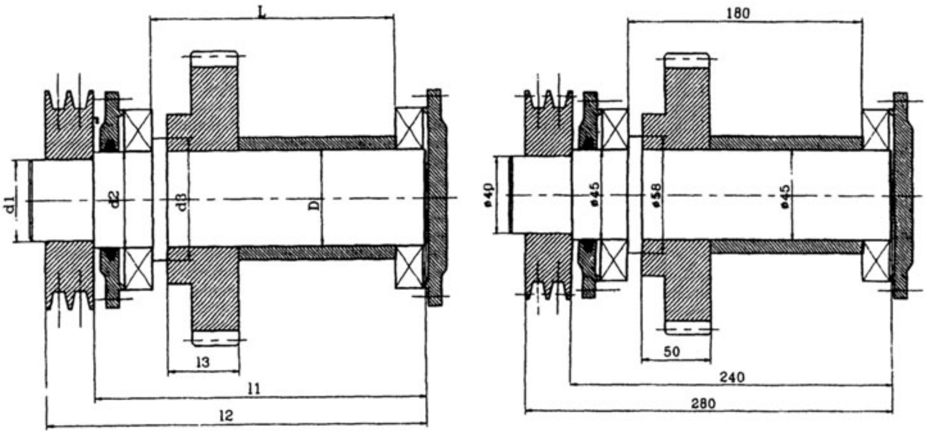
Table 1 The initial design parameters

Maximum torque	M	Shaft material	H
Distance between bearings	L	Shaft diameter for gear mounting	D

Table 2 Relationship of current design parameters vs initial design parameters

current design parameter	*express by initial and other design parameter*	*others*
d1	f(M, H)	rounding
d2	D	rounding
l1	L + 2 x bearing width + bearing cover +2	rounding
2	> l1 + pulley width + 2	rounding
l3	f(M, H)	rounding
d3	> d12 + 10	rounding

After we finish the design at this level, we can further decomposed it into 5 parts and let more engineers to join the design team. The parameter passing from this level to next level is listed in Table 3.



(a) The shaft assembly to be designed (b) The refined shaft assembly

Figure 3 The shaft assembly design

Table 3 The inheritance relationship between design parameters

Parts	*d1*	*d2*	*d3*	*l1*	*l2*	*l3*	*D*	*L*	*bearing type*
shaft	□	□	□	□	□	□	□	□	□
bearing cover		□			□		□		□
pulley	□			□	□				
gear						□	□		
axle sleeve						□	□		

It is clear fron the discussion above that every design step gets some inherited information from its upper hierarchies and adds some new information to the design. These infomation together will be passed to the next hierarchy as initial design constraints. This kind of association ensues the assembly model to be unique and consistent in the entire design and modification process.

In this example, if the design parameter "maximum torque" is changed, not only the calue of D in the same assembly hierarchy will be affected (Table 1), but also all the related parameters d1, d2, d3, l1, l2, l3 at the shaft assembly level will be chaiged accordingly (Table 2). This propagation mechanism guarantees the consistence of the assembly model.

4. IMPLEMENTATION CONSIDERATION

Plastic encapsulation mold is used to encapsulate IC chips. It consists thousands of components. Its high manufacturing and assembly accuracy requirement increases both the design cost and time. To ensure the accuracy requirement, the mold is designed in a top-down fashion so that all related dimensions of different components in different assembly hierarchies is defined only once and referenced as many times as it is needed. According to this requirement, we designed a particular CACD system with the following features:

- It has an assembly model to represent the layout design of the mold. The layout design is the critical step of the mold design. All the assembly dimensions and constraints are specified in this global model for further reference.
- The layout assembly model is composed of a set of sub-assemblies and parts. Every dimension in the layout assembly is stored in a global model. All other parts constrained by this dimension will reference it.
- The design is started from the layout design. When the layout design is finished, a set of tests is performed on the layout design to check the manufacturability and assembly condition.
- After the layout design is completed, it is decomposed into sub-assemblies for detail design. All the design work thereafter are forced to use the data stored in the global model if they are available. This ensure the design consistence across the entire design process.
- Super-2D parametric design and drafting technology [3, 4] was implemented to handle parameter changes at any design stage. Once a design parameter in the global model is changed for example, all the reference will be changed accordingly, as well as those derived dimensions associated with this dimension.

The system structure of the plastic encapsulation mold CACD system is shown in Figure 4

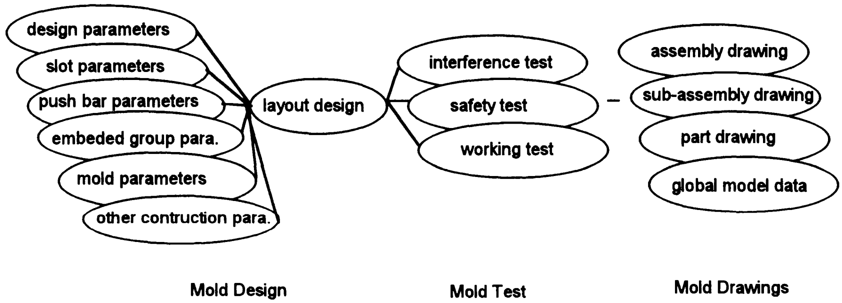


Figure 4 Plastic encapsulation mold CACD system

5. CONCLUSIONS

From the discussion above, We conclude that:

- The part oriented CAD systems today can not support product designs; therefore can not meet the demands of CE and CIMS.
- Product oriented CACD technology proposed in this paper, starting with an assembly model, can support the entire process of a product design. Together with other technologies like product model data management, process management & control and an inteoprable integration framework, it can support concurrent design for CIMS.

Concurrent design and product modeling are two hot research subjects today. They are closely related to CIMS and CE implementation. In the future study, we will focus more closely on the assembly model construction and the inheritance mechanism among different assembly hierarchies and different assembly components and associate our study together with the international study on STEP.

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