Research on Digital Models for Product Design and Manufacture[*]

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Abstract: CAD/CAM integrate technology has been drawn to much attention and becomes one of the focus of the international academic and commercial research, Through efforts nearly 10 years, remarkable progress has been made in the 3-dimension feature parametric modeling. UG、SOLIDWORK and MDT apply these technology with respective features. However, no distinct development has been made in the digital models from geometric feature to manufacture feature. Product information expression and the basic model frame of data exchange have been proposed based on STEP standards, but it is quite difficult to some extent ensure the operability, due to the complexity in application. The models addressed in this paper divide the shared digital models (not data models) for product design and manufacture into five parts: ①Digital product 3D molding design; ②Digital product technology process design; ③Digital product assembly design; ④Digital product manufacture process design; ⑤Digital product management design. The resource model should not be included. And It should be a peripheral model in product design; which is the innovative viewpoint of this paper.

The core of above -mentioned five models is to access the digital model from the solid unit feature. Product definition should be determined on the basis of solid unit, and solid unit should follow the rules of "generation of machining processing", Therefore, the author also proposed the Constructing Cutting Geometry Method (CCG) in IMCC'2000. In this way, the integration of "forming — processing — assembling — machining — management" can be obtained. This is the core originality of the paper.

Key words: product digitization, solid unit technique, CAD, CAPP, CAM

1. Introduction

Before discussing digital models on product design and manufacture, it is necessary to clarify what digital product design and product digitization technique is?

For example, some people may think, "digital manufacture technique is to apply digital technique to support the whole life cycle of product manufacture activities and to optimize the operation of the enterprises; and digital products can be obtained by utilizing digital technique in industry products. And the combination of information technology and manufacture technique will make manufacture technique digitized step by step." This is a lopsided comprehension without understanding the innate character.

Product digitization is much different from digital products. Product digitization：take the part digitization for example, includes class code feature of solid Unit、assemblage style feature of solid unit 、shape feature of solid

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unit、physical feature of solid unit、manufacture feature of solid unit、description feature of part、assemblage feature of part、information feature of part drawing etc. The process of turning the digital information (such as the parameterized sizes) and the non-digital information (such as physical information: steel 45#) into digitizing information (including digitals, arithmetic operation signs and logical operation signs) through digital models is product digitization. Digital product design is to digitize the products and thus to make the products digitized. (Namely they will have digitized features such as body unit features, process technique features, manufacture features, interrelation features and code features). Mechanism design, optimum design, finite element analysis and simulation design, technique process and manufacture process design can be carried out through information technology ……etc.

2. Digital models on 3D Solid Unit

The minimum unit of product has been disassembling as "Part" for a long period of time. Thus "Group Technique" was proposed and product parameterization was studied. Therefore, a lot of CAD/ CAPP researches are based on the group technique now. However, CAD ideas must be changed in order to realize 3D basic element on which the modern CAD technique based. Now 3D basic unit, called solid unit, should be adopted.

This article proposes 3-Dimension Solid Unit Digital Models (SUDM) for the very first time on the basis of these researches. These solid units must conform to the manufacture process regulations, and must have the apparent parameter characteristics and the generalities of composing solid elements.

2.1 The sort and code of 3D solid unit:

3D basic solid units can constitute to compound entity (every kind of parts), for the phantasmagoria shaping type, can use compound parameter solid unit to construct. According to the machining forming principle, it can be categorized into the flowing type of the basic solid unit :

1) Simple solid unit: 01Cylinder, 02 cone, 03 box, 04 sphere, 05 wedge, 06 ring body, 07 torus, 08 rectangle ring, 09 trapezium ring, 10 triangle ring.

2) Function type solid unit: Such as the spring, flowers key, gear etc., only the solid unit can be acquired by the calculation method as function.

3) Feature parameter solid unit: They can be constructed by creating a standard parameter library to construct solid unit. Such as: Bolt, Nut, Spherical head key...etc.

4) The vertex fitting solid unit: Such as the stochastic shape shell, only by extracting random dot to fit to construct solid unit, but after the feature filtrating to get the parameter.

5)The self-definition of the solid unit: The main cross section is self-definition and provided with the parameters, this shaping can be formed by extruding.

The disassembled solid units of above-mentioned by the identified technology of the parameter feature in favor of the behavior modeling, the realization of intelligence design of construction product according

Figure 1 Code of 3D solid unit

to the function, and the realization of 3D shaping design by the object drive, and self-adaptive graphics control.

The solid unit codes include three aspect contents: extracting Part number from Part code, solid unit code, network code of the Part integration. For example, a trapezium bolt is shown below:

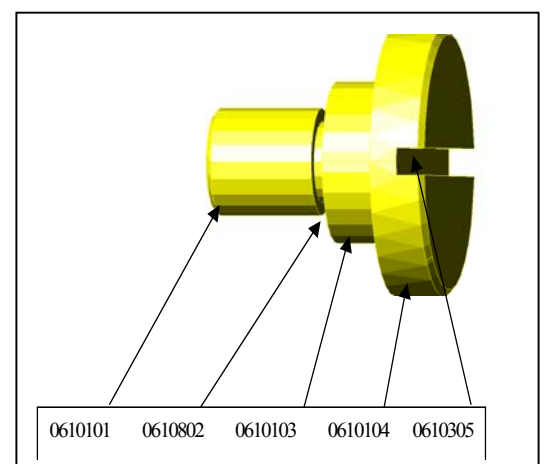This part (part number :06) is composed of five simple solid units(see Figure 1):

Cylinder 0610101   Rectangle 0610802   Cylinder 0610103

Cylinder 0610104   Box cube 0610305

Figure 2

The front two bits are Part numbers, the middle three bits are solid unit codes, and the last two bits are for gathering the order number, thus network code of the Part integration is formed. A part is constructed by the Boolean operation among these units.
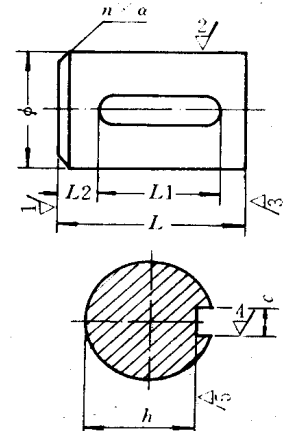
2.2 Feature model of 3D solid unit:

Part feature model must create on the solid unit feature model, the feature models of solid unit are based on the solid unit feature design and identification. the method of shape feature design for solid unit has been discussed in section(See Figure 2)

2.3.The part-orientation feature modeling：

We can think, the product feature is composed of features of some solid units, and the feature of each kind of solid unit geometry (SUG) is attached to the database, which belong to the features, offering the data for input in the modeling. The feature model is product-orientation design and production process.

The following example shows the construction of data model related to feature parameter (the journal with the key slot). Solid unit classification principle and feature extraction technique are adopted. Entity should be created on this solid modeling, but 3D CCG should comply with the machining rule.

Table 1: Feature model

Main Body data	Main Feature parameter	Feature	SU_name	Feature_ID	D	L		
		Property	C	C	N	N		
		Value	10101cylinder	01	50	72		
	Machining Feature	Feature	surface name	precision	roughness	Control_PT		
		property	C	C	C	L		
		value	0101cylinder	IT7	1.6	T		
	Technique Feature	Feature	Surface name	redundancy	Heat treatment	Work material	rigidity	remark	Path
		property	C	N	C	C	C	C	C
		value	0101cylinder	2	TZ	40Cr	HB210		parallel
	Techniqu e Feature	Feature	Surface name	batch	Machining	Tool_material	speed	depth	feed
		property	C	N	C	C	N	N	N
		value	0101cylinder	1	finish		120	1	0.15
Surface Data	Function Feature	Feature	SU_name	Child_unit	Feature_ID	C	H	L1	L2
		Property	C	C	C	N	N	N	N
		value	10101cylinder	30402 round_Key	0102	14	44.5	5	63
	Assistant Feature	Feature	SU_name	AU_name	Feature-ID	N	A		
		Property	C	C	C	N	N		
		value	10101cylinder	Chamfer	0101	2	45		

In the table, the main solid unit is namely on embryo of solid unit and a function solid unit (son unit) is the envelop body developed by the tool during the machining (such as slotting, punching), the transition solid unit (assistant unit) is formed in assistant machining (such as: chamfer, filleting), by this way shaping conforms to the concept of process molding.

Because CAD and CAPP differ in their application emphasis and purpose, they must have the correspondence and correlation relation on the feature extracting. Feature modeling must expediently edit the feature parameters according to craft shaping principle (delete, modify, inherit, search, substitute etc). For this reason product feature

is the combination geometry solid unit embodied some technique attribute with manufacture feature, it is correlation between manufacture feature and design feature.

2. 4 Parameter database model of 3D Solid Unit

Parameter database model of 3D **SU** is according to principle of the Construction Cutting Geometry method (CCG).

1) Basic database model (GDBM): such as technique requirement, title bar, drawing frame etc.

2) Feature parameter database model (FDBM): The description of the body's basic geometrical feature, self-adaptive feature (such as: size restriction, shape analysis, cutting simulation, flow-process design, function optimization etc.)

3) Construction product database model (CDBM): The relative coordinate system、coordinates、movement attribute、relation attribute and construction method of the assembled construction product shaped by a solid unit.

4) Technique attribute database model (TDBM): The attribute attached to an appertained solid unit, such as the material、accuracy、machining type、fitting property etc.

5) Solid unit function database model (UDBM): Function parameters adapted to the need of an engineering, namely the primitive data of product design.

Database models Above, can be a relation type、table type、text type and description type, or the synthesizing among them.

3. Digital Model of 3D Solid Unit's technical planning

The technical planning design is primarily composed of information of the surface on solid unit digital model. Actually, It is to create a model composed by "description information of part + feature information of machining surface on the solid unit + feature information of no-machining surface on the solid unit " which is called "technical model".

Figure 3 The macro-construction of a technical model

CAPP system products-orientation requests to create a criterion "technical model" on solid unit, and make design system of the computer technical planning, from which the information can be read, realize the automatic building of a technical planning.

The model shown in figure 3 is the macro-construction of a "technical model"：The whole model adopts some sub-models, which are quoted mutually, completely combining the shape information with the machining information requested by the solid unit, and then organically forms the bases of solid unit code system.
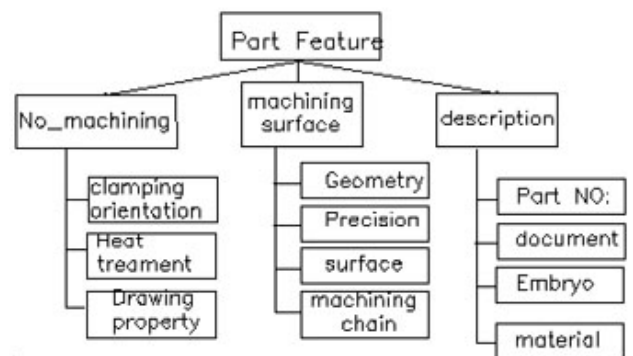
3.1 Machining surface coding principle on product-orientation 3D_CAPP

The "Construction model" describes information of a part and their correlation, which can be expressed by the multi_trees construction, or hierarchy. A part's shape is described with its solid unit feature, according to the cutting path of the machining surface and their shaping character, their interrelation and affiliation to construct the feature construction of a part's cutting surface. The whole information and the size chain of the part can be formed by the macro-construction of part code system about " technical model ".

Stipulated code: feature marking of Solid Unit, SU_ ID=01~99; Main Feature Surface marking, MFS_ ID=01~99, marking from left to right, 01~99 is the marking sequence of main face; Machining Surface marking, MS _ ID= XX01~XX 99, XX among them is the sequence values of SU_ ID, 00~99 is the sequence of Machining Surface. Processing method is superior to sequence code in three- bit code. The description of machining surface feature is

performed according to firstly the outside and secondly the inside sequence, The outside shape feature description is performed then according to the sequence from left to right, while the inner shape feature is according to the sequence from   outside to inside.
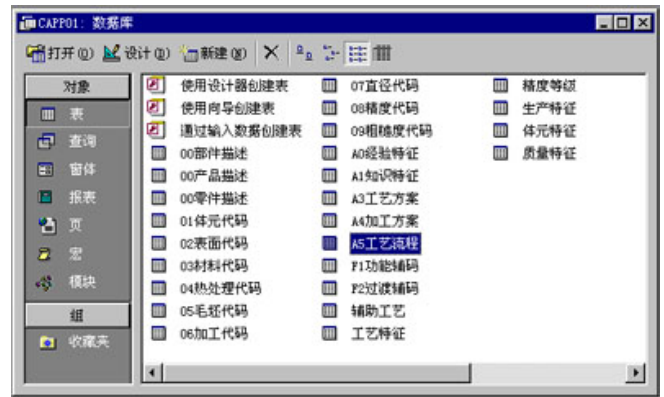

Figure 4 Technical Model

3.2 Research principle of the technical model on product-orientation 3D_CAPP

The sub-models in the "Technical Model " can be expressed by relation model, at the same time they can create correlation relation mutually, the following chart shows the construction of the " Technical Model ":

The key of each sub- model design is the design of the data construction, which must be to reflect technical feature, and be beneficially analyzed by expert system; In each models, Not only the coupling degree should be small, and the polymerization should be higher, but also the feature digital must be realized at the same time.

3.3 Research theory of the technical document on model product-orientation 3D-CAPP

The traditional generative method CAPP is a very complicated problem, However CAPP become simple after the adoption of 3D-CAPP generative method of solid unit technique , so called 3D_CAPP. The product model of 3D_CAPP technologic document is a system model, constituted by some sub- models, the system frame is shown in the following   (Figure 5). Technology experience base, technology knowledge base, the choice of procession project, the decision-making base selection of The technology project (machining chain), the intelligent base of Technology plan is generated, and decision-making base about the arrangement of assistant technology (including: The fixing and clamping of part, the arrangement of heat treatment etc.), all are handled in the regulation of digital code on solid unit, all the craft decision adopt the database to drive combination with the decision of the intelligent logic, making the workload of the editing of the procedure turn down to minimum, thus numbers of the database (or Tables) also become minimum,   and the data construction
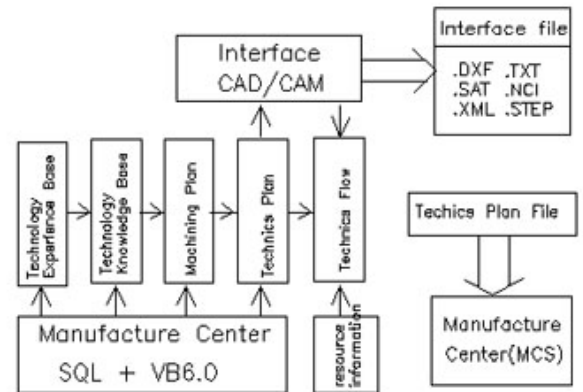

Figure 5

become compact and reasonable , Because it thoroughly gets rid of   the restriction of technique GT , after adopting the solid unit integration and the craft technique, the solid unit is digitalized, urging the product digitalized, and realizing the design of digital product. .PDM designed in this foundation can interactively manage and maintain for production digital connected with shared databases、process、resources ,   for control and management on the generation of technologic document .A complete 3D_CAPP planning should contain the following process：

Part_3D_CAD→CAPP→CAM (preposition)→Tool Path design (CNI)→CAM (postposition)→Numerical Control document(NC) → Remote control(DNC) → On-line machining

4.   Conclusion

The construction method of 3D_CAD/ CAPP/ CAM/ DNC product design and manufacture model is making

shape design in the principle of "the product of manufacture craft". Its main content is the technological design of NC processing, in the core of the design of the tool path, by the method of selecting technological data automatically. It can realize the normalization of solid unit, property of solid unit and design of the tool path. Moreover, it can realize generative CAPP for technique digit of solid unit with creative thought, the digital function system with the integration of CAD/CAM/DNC.

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