A Precision Model Based on Functional Surface and Its Application in Product Reverse Engineering

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***Abstract*—With a view to reverse design of product layer, a tri-level precision model of product-part- functional face based on functional face was organized. The product's precision information model was recovered from the 3D model, and the precision design was achieved. The implementation process of precision reconstruction was introduced in detail and a piston fixture was presented as an example for validation.**

Keywords- recovery; functional surface; precision model; precision design

I. INTRODUCTION

Reverse engineering is a speedy path to improve the level of design and manufacturing[1]. However, researches of reverse engineering nowadays mainly concentrate on the imitation of part structure[2,3], while tolerance design is the key point to balance the performance and manufacturing cost of a product. In paper [1] and [4], studies of the recovery of design parameters and product reverse engineering were introduced. Yet the research of reverse engineering of product tolerance is rarely referred to. And a tolerance model, which is built on the basis of a concept of functional surface[5], merges tolerance information and product tolerance together, enhancing the design level of product tolerance.

II. A TOLERANCE MODEL BASED ON FUNCTIONAL SURFACE

"Functional Surface" is a kind of surfaces that bears the information of "Function-Structure" mapping[5]. And tolerance model is a kind of information model, which expresses the restrictions such as distance, location or between part surfaces in a product. To meet requirements of part interchange and tolerance, a tolerance model based on functional surface is set up to express the tolerance information between surfaces in a product.

A. Tolerance item model.

Given a part P, suppose its tolerance target functional surface as FaceI, tolerance base functional surface as FaceJ, base dimension as D, upper deviation as$\delta 1$,lower deviation as $\delta 2$,then the tolerance item can be expressed as {Tt， FaceI，FaceJ，D，$\delta 1$，$\delta 2$}, in which Tt refers to tolerance type. In the product tolerance model based on functional surface, a product is described by the relationships among its functional surfaces. Only functional surfaces related to tolerance requirements would be store in product tolerance model, so that all functional surfaces involved contain both structure and tolerance information. The product tolerance model is described below in detail in the form of three layers of "Product-Part-Functional_Surface".

B. Tolerance model of product layer

In the tolerance model of product layer, all tolerance items can be expressed as surface relationships between parts, such as fit tolerance and fit types. In Fig.1, the tolerance item between Surface a in Part i and Surface b in Part j can be expressed as "$Parti_a$－$Partj_b$".

C. 1.3 Tolerance model of part layer

In the tolerance model of part layer, all tolerance items can be expressed as surface relationships inside a part, such as dimension tolerance and position tolerance. In Fig. 2, the tolerance item between Surface i and Surface j can expressed "Facei－Facej".

D. 1.4 Tolerance model of surface layer

Tolerance model of surface layer refers to the tolerance item of a surface, such as form tolerance and out tolerance.

III. REVERSE ENGINEERING OF PRODUCT TOLERANCE MODEL

The tolerance model, which is used for tolerance information storage and expression, is the foundation of tolerance design. Some important tolerance information such

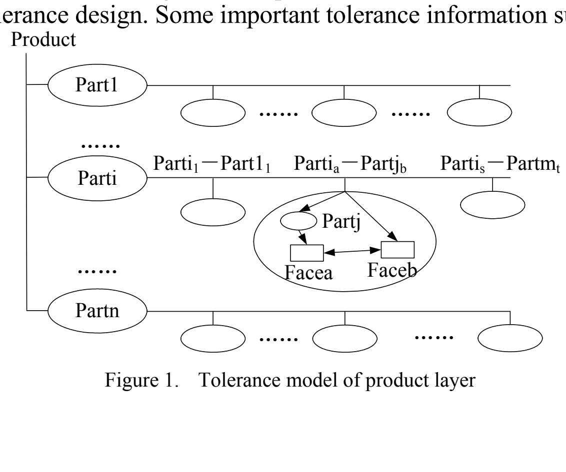

Figure 1. Tolerance model of product layer

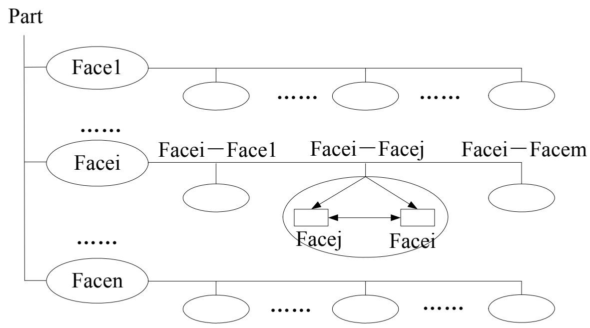

Figure 2. Tolerance model of part layer

as fit relationship and dimension requirement of parts can retrieved from the product solid model. So that a basic product tolerance can be built on the basis of the product solid model, simplifying the tolerance modeling process. Based on a solid modeling platform, a product reverse engineering system supporting tolerance design is developed.

Solid parts retrieved from three-dimensional recovery are geometry models without fit relationships. With the modeling process below, the tolerance model based on functional surface can be retrieved from these geometry models.

A. Tolerance modeling process.

1) Tolerance modeling steps of product layer.

Step1. Suppose *P* as a certain product, *PartList* as the list of all parts of P, N as the number of parts in PartList, Parti as the i'th part in PartList, Partj as the j'th part in *PartList* and Partk as the k'th part in *PartList*. Assign i=0 and j=0.

Step2. If i<N, then go to Step3. Else, go to Step5.

Step3. If j<N, then go to Step4. Else, i=i+1 and go to Step2.

Step4. If i is not equal to j and there exits some fit relation between Parti and Partj, then apply the tolerance item modeling process below to Parti and Partj. And recode Partj as a node of FitPartList of Parti. Then j=j+1.

Step5. All fit relationships between parts are processed.

2) Modeling steps of tolerance item "Parti-Partj".

Step1. Retrieve Parti and Partj with fit relationship, and assign a=0 and b=0. Suppose face_list as a list of all functional surfaces of a certain part, Facea as the a'th functional surface in a certain face_list, and Faceb as the b'th functional surface in a certain face_list.

Step2. Get Facea from Parti and Faceb from Partj.

Step3. Determine whether Facea and Faceb are fitting surfaces by surface type, normal vector and overlap area. If the result is positive, then go to Step4, or else go to Step6.

Step4. Determine whether tolerance item Parti-Partj is the first time to appear. If the result is positive, then add this item in the product tolerance model. Then go to Step5.

Step5. Determine whether tolerance item Facea-Faceb is the first time to appear in Parti-Partj. If the result is positive, then add this item in Parti-Partj. Then go to Step6.

Step6. Determine whether Face(a+1) is null. If the result is positive then go to Step7. Else assign i=i+1 and go to Step2.

Step7. Determine whether Face(b+1) is null. If the result is positive then terminate the process. Else assign j=j+1 and go to Step2.

After the tolerance modeling process based on functional surface, all tolerance items constitute a unify tolerance model adhering to product structure. On the basis of the tolerance items in the product tolerance model, dimension chains can be constructed conveniently.

B. Realization of tolerance design.

1) Tolerance design of product recovery.

In the tolerance design process while product recovery, data retrieved from reconstruction contains errors from wear and measurement. So that it is very difficult to retrieve the tolerance parameters of an actual product. In actual design, dimensions retrieved can only be referred to, and performance, manufacture cost and fabrication condition should be considered integratedly. Tolerance design is generally achieved by dimension chain method. With the product tolerance model, dimension chains can be constructed by tolerance items based on functional surfaces. Closed loops and component loops in the dimension chain can be retrieved by tolerance items of product layer and part layer.

2) 2.2.2 Construction of dimension chain

Construction steps of dimension chain:

Step1. Firstly, assign the requirement of closed loop. Assign tolerance base surface as Face0 and tolerance target surface as Facej, upper deviation as$\delta 1$,lower deviation as $\delta 2$.Then distance vector V between base surface and target surface,which is also the vector of the dimension chain, can be calculated.

Step2. Find a fitting surface of Facej in the tolerance of product layer. And assign it as Facei, and assign the part to which Facei belongs as Parti.

Step3. Take Facei as a tolerance target surface of Parti, and find the tolerance base surface of Parti(The distance vector between Facei and Facej should be equal to V or –V).

Step4. Decide whether Facej is the tolerance target surface of the closed loop. If the result is positive, then the dimension chain is constructed. Else go to Step2 repeatedly.

After the construction process of the dimension chain, all related component loops, dimensions and tolerance requirements are included in the tolerance model, stored together with the structure information of functional surface, ready for tolerance design.

IV. EXAMPLE

As shown in Fig.4, a fixture for semi-fine boring process of a piston's pin hole is taken for example to illustrate the achievement of tolerance design in product recovery.

The piston workpiece can be taken as the origin part to implement the process of tolerance modeling process of product layer. As in Fig.3, there are fitting relations between upper end face of the piston and base plane of the top supporting element, pin hole surface of the piston and outer cylindrical surface of the pin, lower end face and outer cylindrical surface of the piston and inner plane and inner cylindrical surface of the base locating element. So relations

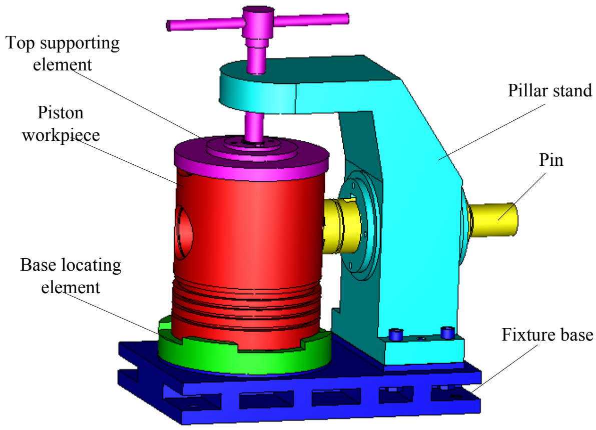

Figure 3. A fixture for semi-fine boring process of a piston

between the pin and parts of the top supporting element, the pin and the base locating element will be confirm firstly. Then all fitted functional surfaces in the fixture assembly will be found successively.

After the recovery process illustrated above, a tolerance model based on functional surfaces can be derived as in Fig.4. All parts in this model are constituted by functional surfaces. In current phase of the tolerance model, all tolerance items are constructed without specific tolerance information such as upper deviation and lower deviation of a certain dimension.

As in the actual semi-fine boring process, the piston is located in the vertical direction by the lower end face and clamped by the top supporting element. So the lower end face and pin-hole surface of the piston can be assigned the base surface and the target surface, then the distance between the two surfaces is the closed loop. And tolerance requirements can be determined by manufacturing requirement of the piston. In the tolerance model of product layer, base surface and target surface of the closed loop, dimension of the closed loop, and tolerance requirements will stored as attached information of tolerance item of the piston. The distance vector of the closed loop can be taken as the dimension chain vector. With the dimension chain vector and fitting relations of functional surfaces, all component loops in the dimension chain can be constructed. As in Fig.5, functional surfaces linked with the dashed line construct the dimension chain.

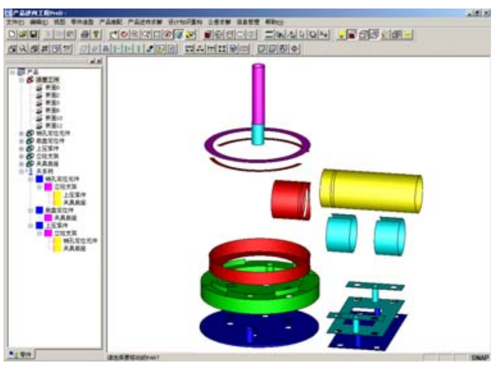

Figure 4. Fixture information model based on functional surface

Suppose closed loop tolerance requirement of the fixture as C, and upper deviation of C as +0.01mm,lower deviation as -0.07mm. Then tolerance grade of each component loop can be determined as 7 grade of standard tolerance based on piston tolerance model. Take D3 of pillar stand as the coordination loop, then following the tolerance item expression illustrated in the preceding text, each requirement of tolerance items can be derived as follows.

V. SUMMARY

The recovery of product tolerance, which is the key point and also difficult point of product recovery, make better reuse of product knowledge. Tolerance design of a piston fixture is processed in with the method in this paper. It is proved that the method of building tolerance model by solid model is simple and effective. Also, the method can transform tolerance requirement to tolerance items easily, which reduces artificial modeling work and provides necessary information for the following manufacturing process design. Therefore, a practical technic approach is provided for product knowledge reuse and subsequent innovation.

REFERENCES

[1] Yang Tieniu. Study on Retrieving the Initial Design Parameters from Objects and Realization Faced on Reverse Engineer[D]. Xi'an: Xi'an Jiaotong University, 2000(in Chinese)

[2] Jian Gao, Xin Chen, Detao Zheng, et al. Adaptive restoration of complex geometry parts through reverse engineering application[J]. Advances in Engineering Software, 2006, 37(9):592-600

[3] Ke Yinglin, Liu Yunfeng, Fan Shuqian, et al. Feature-Based Reverse Engineering Modeler—RE-SOFT[J]. Journal of Computer-Aided Design & Computer Graphics, 2004, 16(6): 799-811(in Chinese)

[4] Guan Tianm, Lei Lei, Sun Yingshi, et al. Inverse Design Used to New FA Series Cycloid Drive[J]. Chinese Mechanical Engineering, 2003, 14(1):68~71(in Chinese)

[5] Chen Hongwu, Huang Kezheng, Yangbo. Research and Implementation on Product Design Automation Based on Function Surface[J]. Machine Design and Research, 2004,20(3):24-27(in Chinese)

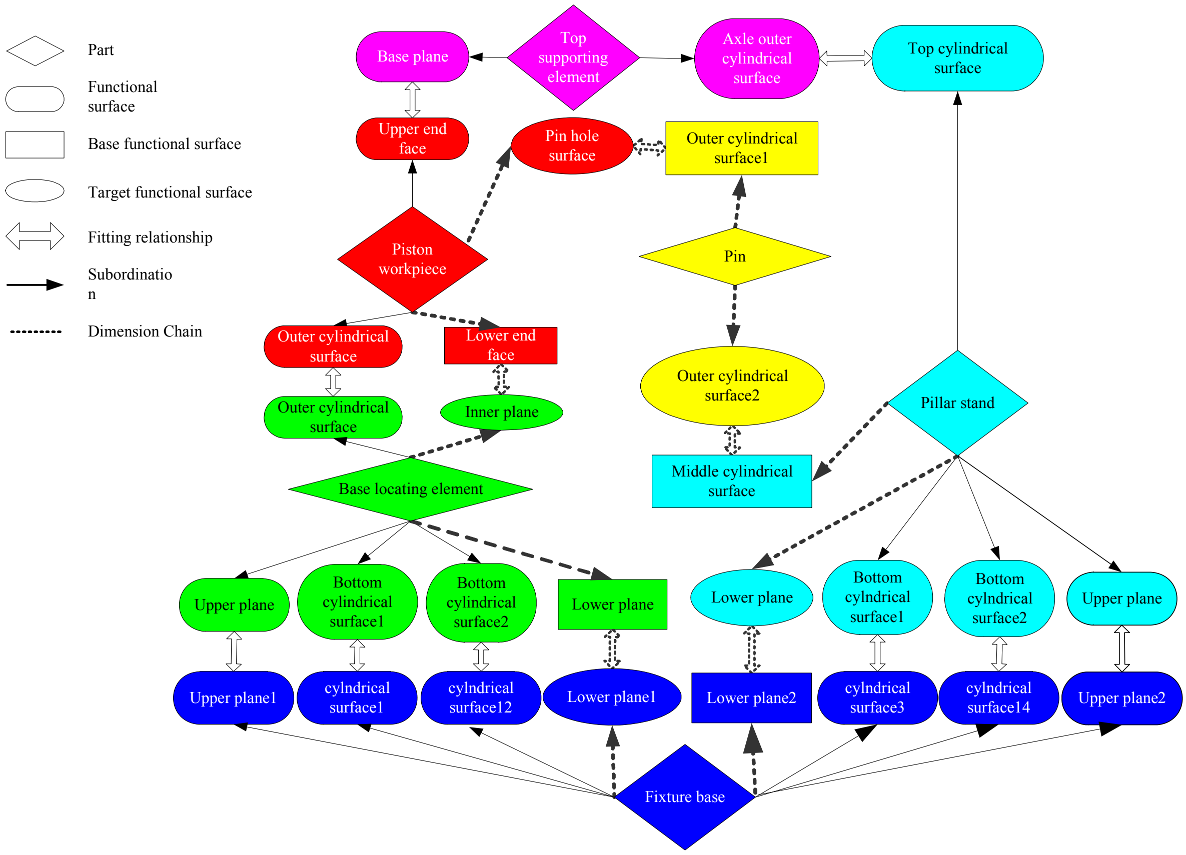

Figure 5. A tolerance model diagram of a piston fixture

TABLE I. RESULT OF DIMENSION DESIGN（UNIT：MM）

ID	Part Name	FaceI	FaceJ	D	δ1	δ2
0	Piston workpiece	Pin hole surface	Lower end face	136.50	0.0100	-0.0700
1	Base locating elemate	Inner plane	Lower plane	28.00	0.0105	-0.0105
2	Fixture base	Lower plane1	Lower plane2	4.00	0.0060	-0.0060
3	Pillar stand	Lower plane	Middle cylindrical surface	160.50	0.0500	0.0100
4	Pin hole	Outer cylindrical surface2	Outer cylindrical surface1	0.00	—	—