Research on Cost Calculation Method of Typical Reverse Design Process

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Abstract: In basis of anglicizing the characteristics of Reverse Engineering Technology-shear layer and optical scanning measurement technology, it is introduced a calculation method of the reverse time and cost based on the analysis of process. This method uses the parametric cost algorithm and the analysis of the unit cost composition, and establishes a mathematical model between process parameter characteristics and manufacturing cost, including the composition of manufacturing cost. On this basis, it establishes a model of the rapid quotation. This model can quickly and accurately calculate cost of reverse engineering task. And it provides a rapid method of quotation which is easy to submit by network for enterprises. By cost calculation of reverse engineering for enterprises, it further illustrates reliability and rapidity of the method.

Keywords: shear layer reverse measurement; 3-D laser scanning technology; model of the rapid quotation; cost estimation

1 Introduction

Reverse Engineering (Reverse Technology) is mainly directed against the existing prototype. It digests and absorbs knowledge and experience of which contains the product design, manufacturing, and other aspects which used as the beginning of product innovation. The digital product model which is obtained by reverse engineering technology have a good convergence with the follow-up products detailed design phase of the technical methods, such as CAD, CAE, CAPP and CAM. The geometric model of prototype by its three-dimensional reconstruction can be directly adopted by the aboved system. This has greatly increased the speed and quality of product design. Reverse engineering which is different with the traditional copying manufacturing, is mainly changed the original physical model into a design concept or design model, and on the one hand it provides adequate information for improving quality and efficiency of engineering design and processing analysis, on the other hand it offers a new engineering service to original physical model for taking full advantage of advanced CAD / CAE / CAM technology. Because the implementation of reverse engineering can copy sample in a short time, it is also an important foundation and technical support for the implementation of concurrent engineering. The design process as shown:

In the real design, it needs to communicate in reverse time and cost between an enterprise which needs a product design and design unit. This requires a scientific and rational calculation of the cost accepted by all. In this paper, a typical cut-and-scanning measurement technology in the reverse engineering as an object, it focuses on a cost analysis. Finally, it establishes a model of the rapid quotation.
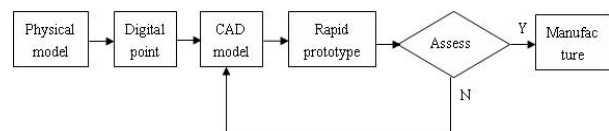

Figure 1. Reverse design process

3-D laser scanning technology and reverse-cutting technology can not be directly used for copying physical prototype of the same things; both of these technologies as typical reverse have their own advantages and disadvantages. Non-contact laser scanning measurement is the direction of 3d freedom surface measurement. Because it uses laser-scanning technology, the measurement results will not be different as the changes of the operators, and heavy precision and high-speed; Layer shear reverse technology is a means of measurement with higher accu-

racy, lower costs and broader application in the fault of 3D measurement technology. This method has characteristics of high accuracy, automatically measurable, objects of interactivity such as shape and size etc. And the equipment costs are much lower than the ICT machine of measurement equipments fault. The main costs of reverse-cutting technology and laser scanning technology are parts of the 3D data acquisition and three-dimensional model construction. According to the process characteristics of layer shear reverse technology and laser scanning technology, the comprehensive cost formula is derived from these two technologies.

2 The Cost Estimating of Shear Layer Measurement Technology

Reverse-cutting technology which is based on layer images is three-dimensional measurement reverse technology; it can achieve the inner and outer contour extraction of complex parts and dimension measurement. From the principle we can see that layer shear reverse technology of based on the principle of layer images has the essence that it separates the objects into a finite number of fault sections, and according to these sections, make reduction on mature digital technology and advanced CAD technology. The reductive model is three-dimensional, so we can do the options on them, such as further modifying, further designing, digital simulation analysis, finite element analysis etc. Compared to other measure technologies, layer shear technology can accurately measure the components of the internal structure with the characteristics of higher accuracy and lower cost.

The cost calculation methods of the existing are: 1) the project cost method: It begins with the work of checking and identification the bottom of work units, and uses the principle of decomposition analysis to calculate costs bottom-up one by one. This approach is detailed calculation method, and generally applied to the latter part of the design and production stage; 2) Cost estimating algorithm by analogy: It is a cost estimating algorithm which is built on analogy with the past similar product and technology experience, and this method of calculation has usually a big error. When the new structure, function and per-formance of products have more inconsistency compared with the past, the error is particularly great; 3) parametric cost algorithm: The basic idea of this method is to get mathematical relations of product cost and product weight, size, performance and other characteristics, according to products historical data which accumulated in working processing. Then we can quickly estimate the cost of products based on this relations after inputting characteristic variables of information.

In this paper, we take this method to establish the mathematical model of process parameter characteristics and manufacturing cost, and we get task manufacturing costs and with the final sale expenses estimating, we have the task cost estimates of user-oriented quotation by the end.

The general cost of the product is composed of the direct labour and direct materials, the factory expenses, general expenses, sale expenses and profit and the final offers of products quotation is also based on this.

Direct labour L_d and direct material M_d, both of sum is called major cost C_p, that is:

$C_p=L_d+M_d$

Sum of the major cost and factory expense is factory cost C_f. Factory expense includes all costs of using rent, heat, electricity, water, each kind of spare parts and indirect artificial cost. The indirect artificial cost includes all artificial costs of not including the direct artificial cost.

Factory Cost $C_f=C_p+$ Factory Expense

Sum of the factory cost and general expense is manufacturing cost C_m. In the production process, the general expense supposes the cost including the project, the purchase expense, the office personnel salary and the thing as well as the depreciation expense. The cost of production is called manufacturing cost.

Manufacturing Cost $C_m=C_f+$ General Expense

When we determine quotation of products, compensating manufacturing cost of products is merely insufficient. In product sale processing, we also must increase expense of all sales and the transportation product. These expenses possibly include the advertising expense, the bad debt loss, the freight, the salesman wages and commission. Sum of the manufacturing cost and selling expense is total

cost.

Total Cost $C_r = C_m +$ Sales Expense

Finally, the quotation of product facing user is obtained by total cost adding on stipulation marginal profit, in the table 1 as shows:

Table 1. The composition of product cost

According to analysis for product cost composition, the manufacturing cost of layer shear technology is a composite of artificial cost, direct material and equipment cost. In which the artificial cost is determined by work load size, however, the work load is determined by data quantity which is processed by layer shear technology. In layer shear technology, the most important step is three parts of the data acquisition, the point cloud extraction and the model restructures. Usually in the layer shear reverse process, the data acquisition and the point cloud extraction carry on taking the level as a unit. The point cloud data quantity size is determined by quantity of layer. This is directly affecting the model restructuring work load size, in other words, the size of artificial cost is determined by data quantity.

$L_d =$ labor cost of unit time× (layer shear reverse time+ spot cloud extraction time)

$$L_{D=} r \times (T_b + T_w + T_M + T_d/60) \tag{1}$$

Where: r---- labor cost of unit time, unit: Yuan/hour.

The expense of direct material is produced by the embedding material, whose calculation model is as follows:

$$M_d = [(A+3) \times (B+3) \times (C+3)] \times \rho \times \Phi \tag{2}$$

where: A、B、C--------the greatest size of being measured components with all quarters approach, the single side pulsing 3cm, unit: cm;

ρ ——the density of resin, $1.11 \mathrm{g/cm}^3$;

Φ ——the unit price of embedding material, unit: Yuan/g.

Where: the equipment of layer shear work and factory expense of consumption mainly include rent of location, electricity, as well as cutting tool which is consumed. It is expressed with λ .

It is the most main by the equipment cost in the general expense. The equipment cost is mainly determined by the depreciation expense of equipment D, which is estimated with following method: it is supposed that the equipment service life is n, the total expense of the production period is Q, the total output is B, the unit cost of the product in the whole productive period is $Cx=Q/B$，if output of Kth year is B_k, the depreciation expense is D_k, direct material expense is m_k, other production cost is G_k，then the depreciation expense is

$$D_k = Q \cdot B_k/B - m_k - G_k \tag{3}$$

According to the analysis of above cost constitution, combining the technology characteristic of layer shear reverse, we obtain the mathematical model of basic quotation on layer shear reverse which is:

$$\begin{aligned} M &= L_d + M_d + D_k/B_k + \lambda + S + \gamma \\ &= r \times (T_b + T_W + T_M) + T_d/60 + [(A+3) \times (B+3) \\ &\times (C+3)] \times \Phi + (Q \cdot \frac{B_k}{B} - m_k - G_k)/B_k + \lambda + S \\ &+ \gamma \end{aligned} \tag{4}$$

where: λ ——the factory expense, including rent, water, electricity and so on;

S ——the sales expense;

Υ ——the profit.

3 The Cost Estimating Of Optical Scanning Measurement Technology

3-D laser scanning technology reconstructs the panoram three dimensional data and model of target from the complex entities. It mainly gains the goal on line, surface, body, space and so on three dimensional measured data. And it implements outer contour extraction of complex entities and the digital reconstruction of prototype. It can be seen from the principle that each scan point cloud

which is measured by using three-dimensional laser scanning technology is based on the principle of triangulation measurement. And according to the sensor-driven of laser scanning, it carries on measurement of the three dimensional direction to step-by-step. Then according to the measurement data of point cloud, it makes reduction on using advanced CAD technology. Subsequently we can do the options on them, such as further modifying, further designing, digital simulation, finite element analysis etc. Compared to other measure technologies, 3-D laser scanning technology can accurately measure the components of the internal structure with the characteristics of higher accuracy and lower cost.

The production cost of Optical scanning technology is mainly from the artificial expense, the equipment depreciation and the factory expense, direct material expense, the sales expense and the profit and so on, which is same to layer shear technology. Optical scanning is usually used fewer types of materials and equipment, whose direct material expense is single, mainly reagent (also known as the coloring agent detection) loss; the equipment depreciation expense is from the decline of laser life of 3D laser scanner; And the cost of labour, mainly from the acquisition of point cloud data processing, which closely relates to the complexity of measured parts. Optical scanning technology on the operating cost model is as follows:

$$
\begin{aligned}
M &= L_d + D_k / B_k + M_d + \lambda + S + \gamma \\
&= r \cdot [(i \cdot L / l \cdot 3600 + \delta) + \\
&\quad (\alpha \cdot \ell \cdot \chi + \beta)] + (A \cdot B_k / B - m_k - G_k) \\
&\quad / B_k + M_d + \lambda + S + \gamma
\end{aligned}
\tag{5}
$$

where:

L_d——the labor cost;

D_k/B_k------ the equipment depreciation charge of the single unit product;

M_d------used charge of direct material;

r——the labor cost of the unit time;

λ——the factory expense;

S——the sales expense;

Υ——the profit.

4 Conclusions

In this paper, according to the characteristic of layer shear measurement technology and 3-D laser scanning technology; it studies a calculation method of fast reverse cost based on the process analysis and the quotation model.

(1) Take parametric cost algorithm to establish the mathematical model of process parameter characteristics and manufacturing cost, and we get task manufacturing costs;

(2) Analysis on the unit cost composition of 3-D laser scanning technology and establish the operating cost model of laser scanning technology;

(3) Establish a model of the rapid quotation. This model can quickly and accurately calculate cost of reverse engineering task. And it provides a rapid method of quotation which is easy to submit by network for enterprises;

(4) The reliability of time which is calculated by this method is further examined, through which the error analysis processing between time of enterprise actual design and calculating time. This method provides a kind of tool which is scientific and reasonable, efficient and rapid.

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