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Study on Rapid Product Design Based on Forward and Reverse Hybrid Modeling

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ABSTRACT

In the daily use, the products can be broken for improper use. The traditional product development methods applied in reverse reconstruction process are inefficient and poorly accurate. In order to enhance the ability of rapid design, the paper applies the integrated forward and reverse hybrid modeling technology, realizes the fast parametric reconstruction of the product. The crane hook's parametric reconstruction has been chosen as research objective and tested the proposed approach.

INTRODUCTION

The traditional product development process has a long design cycle, and it cannot effectively integrate advanced technology of product design at home and abroad[1]. The forward and reverse hybrid modeling, as a new design method, has been a means of developing product original design intent and integrating advanced technology of product design to shorten the development cycle.

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RELATED WORK

Preprocessing of Point Cloud Data

Because the hook has certain deformation wear[2], in order to ensure the accuracy of parametric reconstruction model, propose the segmentation method based on curvature to distinguish the deformed areas from the under formed areas in the point cloud cross section profile[3]. As shown in Figure 1.

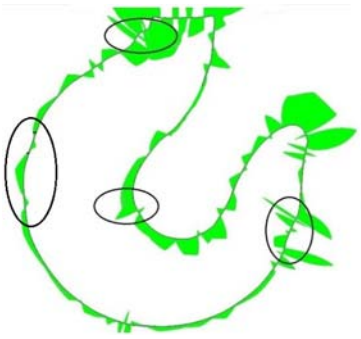

Figure 1. Sectional curvature.

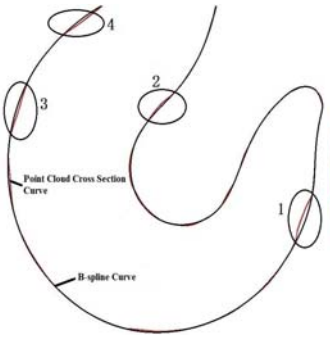

Figure 2. Cross section curve.

Figure 3. Curve curvature.

(1) The curvature calculation of middle points. The curvature value of any point P_i in the $(P_i)_{i=0}^{N-1}$, can be calculated by the circular that is determined by the P_i as the intermediate point of sequence three points P_{i-1}, P_i and P_{i+1}.

$$K_i = \pm\frac{1}{R} = \frac{4\Delta P_{i-1}P_iP_{i+1}}{L_iL_{i+1}Q_i} = \mathrm{sgn}(\Delta P_{i-1}P_iP_{i+1})\frac{2\sin\alpha_i}{Q_i} \quad (1)$$

Where: $L_i = \|P_i - P_{i-1}\|$, $Q_i = \|P_{i+1} - P_{i-1}\|$ and $\Delta P_{i-1}P_iP_{i+1}$ is the signed triangular area.

(2) The curvature calculation of two end points. As the end tangent vector is unknown, circular end condition is applied to estimate the two end tangent vectors $\vec{m}_0$ and $\vec{m}_{N-1}$. Take $\vec{m}_0$ for example, by calculating the $\vec{m}_0$ by P_0, P_1, P_2:

$$\vec{m}_0 = (r_0 * c_0)/\|r_0 * c_0\| \quad (2)$$

Where: $a_0 = P_1 - P_0, b_0 = P_2 - P_0, c_0 = a_0 * b_0$, $r_0 = \left[\|a_0\|^2(b_0 * c_0) + \|b_0\|^2(c_0 * a_0)\right]/(2\|c_0\|^2)$

Two additional points P_0^- and P_{N-1}^- are added along the direction of $-\vec{m}_0$ and $-\vec{m}_{N-1}$, satisfying $\|P_1 - P_0\| \geq \|P_0^- - P_0\|$ and $\|P_{N-1} - P_{N-2}\| \geq \|P_{N-1}^+ - P_{N-1}\|$. At last the

curvature of two end points P_0 and P_{N-1} can be calculated according to calculating formula of K_i.

Fitting and Subsection Processing of Section Curve

(1) Firstly, the interpolation points of B-spline curve are placed in the undeformed areas, and combine the relative position between each undeformed point cloud data block to construct the section curve. The fitting of cross section curve will restore the original design morphology of the wear region. As shown in Figure 2 in the area of 1, 2, 3 and 4.

(2) According to the parameter equation of plane curve, the curvature of any point p_i in the curve can be calculated. The calculation of the curvature of the whole cross section curve can be approximate as the curvature of point cloud cross section profile. According to the changes in curvature, it can identify the type of feature points, segment the section curves and initially recognize the base type of each section curve. As shown in Figure 3.

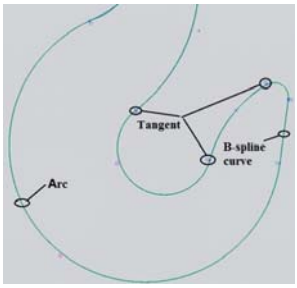

Figure 4. Cross section curve.

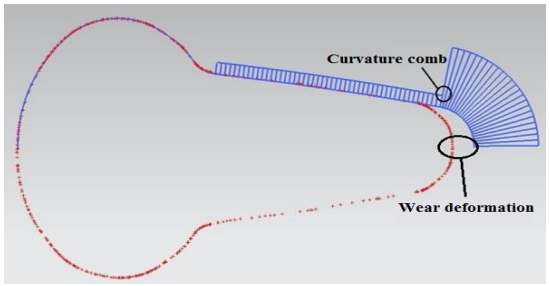

Figure 5. Cross section curve.

(3) After the initial recognition of the basic curve type, it verifies the accuracy of the initial recognition results by fitting the relevant curves based on error controlling method. Take circular arc recognition for example: firstly using least-square method to fit the circular arc, secondly calculating the distance of d_{mean} and $d_{\max}$ between circular arc and point cloud, at last, verifying the accuracy of the initial recognition results based on the preset tolerance σ [4].

Reconstruct Surface Based on Cross-sectional Curve

In order to overcome the flaws and limitations of traditional surface reconstruction method, firstly, it processes point cloud through Image ware and extract the point cloud cross section profile for subsequent modeling, secondly, it

distinguishes the type of basic curve and the information of geometric constraint, thirdly, through the format of IGES, it takes the data of reverse part into UG, and constructs section curve group based on these data with forward design method.

SECTION CURVE PIECEWISE FITTING BASED ON CONSTRAINT

When the base curve type of the wear part in the point cloud cross section profile is straight line or arc, as its shape is known, the parametric composite curve can be made by combination of base curve and geometric constraint. As shown in Figure 4.

SECTION CURVE PIECEWISE FITTING BASED ON CONSTRAINT AND CURVATURE

When the base curve type of the wear part in the point cloud cross section profile is B-spline curve, its shape is unknown. In order to accurately reconstruct the section profile curve, the parametric composite curve can be made based on combination of curvature comb, geometric constraints and base curve. The curvature comb is introduced when drawing the shape of wear part, so that it can adjust the shape of the wear part with dynamic viewers. As shown in Figure 5.

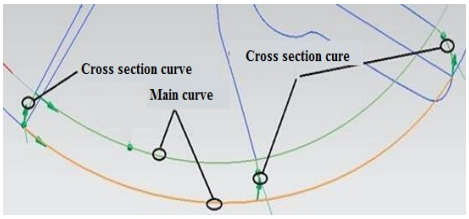

Figure 6. Section curve group.

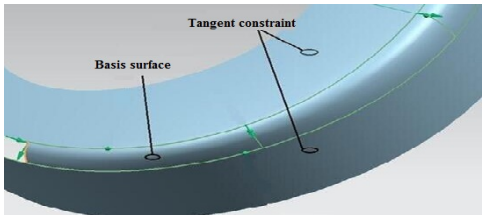

Figure 7. Basis and the transition surface.

SURFACE RECONSTRUCTION

The method of surface reconstruction in the paper is mainly by the command of “Through the curve group” in UG to reconstruct the parametric surface. It is the form of main curve and cross section curve interactive constraint to generate the surface. The Figure 6 is the selection graph of main curve and cross section curve. The basis and the transition surface are reconstructed by this method, and stitches these surfaces through the Sweep, Blend, Lofting or Boundary to ensure the continuity of G_0, G_1 or G_2. As shown in Figure 7.

CONCLUSION

According to the forward and reverse hybrid modeling technology based on the combination of the Image ware and UG, the paper realizes the parameterized

reconstruction, repairment of wear and deformation and restores the shape of the original design of the hook. The experiments results show that the proposed method can effectively fuse the existing advanced technologies, shorten the development cycle, and realize the rapid design of products.

ACKNOWLEDGMENTS

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