

The blank design and spring back control of a stamping die by using the bi-arc surface model

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Abstract

In this paper, a bi-arc surface model is proposed to fit the scanned point clouds of a stamped part obtained by the reverse engineering. The proposed model is capable of obtaining more uniform curvature distribution than the fitting of NURBS surface. The proposed bi-arc surface model is easier to meet and control the parameters of the face of golf head. The specifications for the horizontal and the vertical arc radii design are retrieved from the scanned data. The integration of bi-arc surface model and energy method is proposed to design a developed blank. The springbacks of the trimmed parts of the different blank and die designs have been analyzed. The maximum amounts of springback of using a regular square blank and a developed blank design are 0.6 and 0.14 mm, respectively. The further design of using drawbeads can lower the springback to the amount of 0.05 mm. The proposed bi-arc surface model can maintain the design parameters and integrate the energy method to obtain a better developed initial blank. The springback control of the developed contour blank is better than the square blank design.

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Keywords: Bi-arc surface model; Stamping die design; Springback control; Reverse engineering

1. Introduction

In the metal forming industry, stamping is the major process to make the sheet products, such as the inner and outer panels of a car, the metal covers of mobile phones and note book computers, the container of batteries, and the striking face of golf heads. The reverse engineering is a very popular method to convert the physical object to a 3D geometrical model. Tasi and Chen [1] adopted the reverse engineering technique to generate the suitable mesh for FEM analysis. The scanned random cloud points were sorted and modified to obtain the uniformly distributed points. Lin et al. [2] used the LS-DYNA software to evaluate the effect of different drawbead shapes. The evaluated results were applied to the drawing die design of a lid component of car. Xue et al. [3,4] proposed the energy method to predict the springback of the double-curvature forming. The membrane and plasticity theories were assumed in their discussion. Park et al. [5] combined the ideal deformation and FEM analysis to design the optimum blank of drawing. The ideal deformation [6] assumed the material was deformed with the minimum energy consumption and uniform deformation path. In this paper, the energy method [3,4] was integrated with the bi-arc surface model

to obtain the developed blank. The LS-DYNA was adopted to evaluate the forming and springback processes.

2. Theoretical methods

In this paper, the striking face of a golf head is created by using the reverse engineering technique. The face is rebuilt using the proposed bi-arc swept surface model which the driving and the section curves both are arc. The purpose of rebuilding the striking face via bi-arc surface is to obtain smoother curvature and retrieve the exact arc design parameters of the golf head. There are two blank and die designs proposed here, the regular square blank and the developed blank, for golf head stamping. The drawbeads are also designed to further control the material flow and springback of the trimmed product.

2.1. Experimental procedure

The proposed bi-arc swept surface model is generated by using the driving and section arcs which are correspondent with the horizontal and the vertical arcs of the face of golf head, respectively. The mathematical representation of the swept surface model is given by

$$x_d = x_0 + R_d \sin \theta, \quad y_d = y_0, \quad z_d = z_0 - R_d \cos \theta \quad (1)$$

$$x_c = x_d + R_s \sin \theta, \quad y_c = y_d, \quad z_c = z_d - R_s \cos \theta \quad (2)$$

$$x_s = x_0 + R' \sin \theta, \quad y_s = y_c + R_s \sin \phi, \quad z_s = z_0 - R' \cos \theta \quad (3)$$

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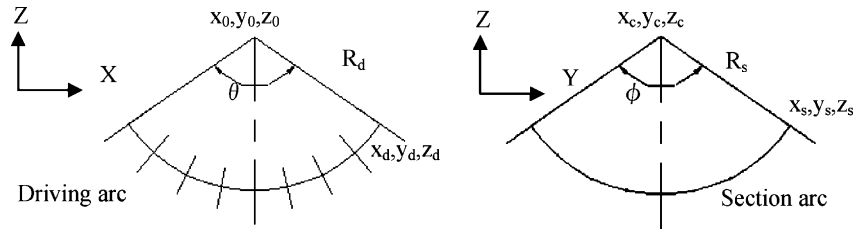


Fig. 1. The driving and section arcs of the swept surface model. The mathematical surface model consists of the driving and section arcs.

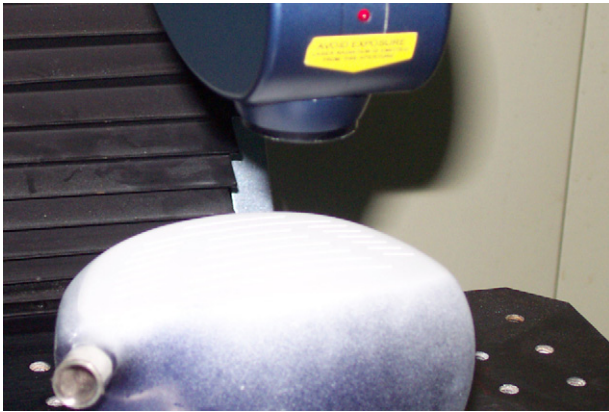


Fig. 2. The golf head model and the optical scan machine (Hawk 222).

$$R' = R_d - R_s(1 - \cos \phi) \quad (4)$$

where the subscript 'd' and 's' represent the driving arc and the section arcs, respectively. The subscripted 'o' and 'c' represent the center of the driving arc and the section arcs, respectively. The angular coordinates of the driving and the section arcs are represented by θ and ϕ , respectively. The notation and the geometrical relation of the driving and the section arcs are shown in Fig. 1. The bi-arc surface model is integrated with the energy method [3,4] to predict the strain distribution of stamped parts. The initial blank contour is obtained by using the length of the driving and section arcs first. The size of developed blank contour is modified by using the predicted strains of the energy method [3,4].

2.2. The reverse engineering technique and the design parameters of a golf head surface

The physical model of a golf head and the Nextec Hawk 222 optical measurement equipment is shown in Fig. 2. The surfaces of the golf head are scanned point-by-point and rebuilt by reverse engineering. The scanned point clouds and the rebuilt surface model are shown in Fig. 3. The striking face of the golf head is usually made by stamping and the die design is also crucial. The main design parameters of a golf striking face are the horizontal

and the vertical radii which could affect the performance of golfing much. In order to obtain these parameters, the striking face data is fitted carefully. The locations of the horizontal and the vertical arcs are shown in Fig. 4. The radii of curvature of the surface model in the center of the horizontal and the vertical directions are calculated and adopted to design the driving and the section arcs, respectively. The radii of the driving and the section arcs are 290 and 450 mm, respectively.

2.3. The blank designs and the stamping simulations

The proposed bi-arc swept surface model has been built using the method proposed in Section 2.2. The blank and die designs of regular square and developed contour shapes are shown in Fig. 5, respectively. The bi-arc swept surface model of the golf head is trimmed out by using the contour of striking face and then developed to obtain the blank contour. The LS-DYNA software is adopted to simulate the stamping process in this paper. The material model adopted is power law. The strength coefficient, K , and the strain hardening exponent, n value, used are 509.45 MPa and 0.1973, respectively. The thickness of original blank is 1 mm. The yield stress of material is 176 MPa. The planar anisotropic value R is 1.79. The Coulomb friction coefficient is 0.1.

3. Results and discussion

3.1. The surface fitting of reverse engineering

In Fig. 6, the cloud points of the striking face has been fitted by using the proposed bi-arc surface and a NURBS surface. The tendency of error distributions of the proposed model is more uniform than the NURBS model. This implies the curvature distribution of NURBS surface is more uneven. The maximum fitting errors occurred near the corner of surfaces as a result of the larger variation of cloud data points.

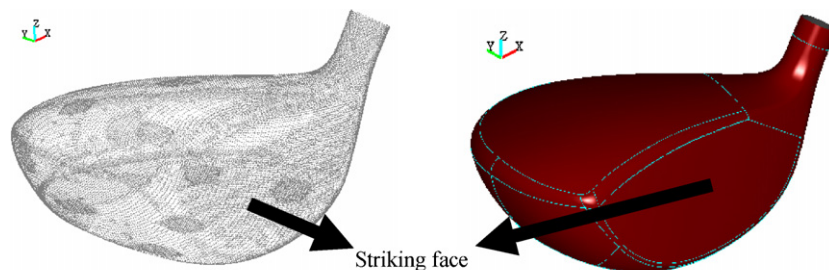


Fig. 3. The scanned point clouds and the rebuilt surface model of a complete golf head.

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