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Application of computer-aided process planning system for non-axisymmetric deep drawing products

S.S. Kang, D.H. Park*

Engineering Research Center for Net Shape and Die Manufacturing, Pusan National University, Pusan 609-735, South Korea

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Abstract

A computer-aided process planning system for rotationally symmetric deep drawing products has been developed. The application for non-axisymmetric components however has not been reported yet. Thus, this study investigates process sequence design and constructs a computer-aided process planning system for non-axisymmetric deep drawing products with elliptical shape. The system developed consists of three modules. The first one is three-dimensional modeling module to calculate surface area for non-axisymmetric products. The second one is a blank design module that creates an oval-shaped blank with the identical surface area. The third one is a process planning module based on production rules that play the best important roles in an expert system for manufacturing. The production rules are generated and upgraded by interviewing field engineers. Especially, drawing coefficient, punch and die radii for elliptical shape products are considered as main design parameters. © 2002 Published by Elsevier Science B.V.

Keywords: Elliptical shape; Production rules; Process plan; Preform

1. Introduction

In general, deep drawing products have various cross-section shapes. For example, there is rotationally symmetric, which is so called cylindrical, square, rectangular and other non-axisymmetric shapes. Many researches have been carried out for cylindrical products that are considered as the fundamentals of deep drawing process. It is believed that empirical experiences and established production methods that are essentially based on trial-and-error procedures can make a successful production, causing substantial amounts of time, money and manpower.

Recently, researches on the computer-aided process planning system for deep drawing process have been widely reported. Park et al. [1] constructed an automated process planning system for axisymmetric deep drawing products. Eshel et al. [2] developed the automatic generation of forming process outlines (AGFPO) system for axisymmetric and monotonic parts, produced by deep drawing. They suggested G&TR (generate and test, rectify) strategy for the process planning of axisymmetric deep drawing products. The system relies on experience-based die-design guidelines for its process sequence design. Altan and coworkers [3,4] developed a knowledge-based system in axisymmetric sheet metal. Tisza [5] presented a group technology and modularity in an expert system. The process planning systems for deep drawing process developed are mostly applications for axisymmetric products up to now, but research for non-axisymmetric products has not been reported. As the products tend to be various at production, however, shape of them will vary diversely. Therefore, it is necessary that application of process planning system for non-axisymmetric products be performed.

This study makes researches of process sequence design and constructs a computer-aided process planning system for a non-axisymmetric product with an elliptical shape. The cross-section of product body consisting of a round in the major axis and a straight line in the minor one is defined as elliptical in the study. This study presents new recognition scheme, three-dimensional modeling technique, a modified Entity_List used to create three-dimensional part modeling, and accumulated production rules for non-axisymmetric products. The system was written in AutoLISP on the Auto CAD software (Release 14) environment.

2. Production rules

The process planning system can be constructed on experienced knowledge of field engineers. The acquisition of knowledge and the representation of them are two of the

* Corresponding author.
E-mail address: pdhwan@pusan.ac.kr (D.H. Park).

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most important tasks in the construction of the system. By interviewing field engineers, production rules are generated and developed. During the interview with them, they are recorded, transcribed and then checked with them before formalizing the rules. In addition, plasticity theories, handbooks and experimental results were referred too. Especially, characteristics of process sequence in elliptical deep drawing products was scientifically investigated. The cross-section of product body, drawing coefficient, punch radius (R_p) and die radius (R_d) were considered as main design parameters. Rules that are distinguished from those of rotationally symmetric deep drawing products are given here:

Rule 1: If the cross-section of deep drawing products was constituted a round in the major axis and a straight line in the minor one, then product is defined as elliptical deep drawing product.
Rule 2: The total surface area of product was calculated by the use of three-dimensional modeling of product based on neutral axis of thickness.
Rule 3: If the input object geometry is elliptical, then blank shape is basically oval.
Rule 4: In computing blank size, trimming allowance is 1.25 times the thickness of blank.
Rule 5: Process sequence consists of cylindrical drawing, preform and top-drawing process.
Rule 6: If a process is first drawing, then drawing coefficient applied must be in 0.54–0.58.
Rule 7: If a process is the last cylindrical drawing, then next process is defined as preform.
Rule 8: If a process is preform, then drawing coefficient applied must be in 0.87–0.9 with the body dimension of the major axis.
Rule 9: If a process is preform, then punch radius between the cup wall and top-part applied must be in 8–10*R*.
Rule 10: If a process is preform, then top-part shape is tapered as 15–45° with cup wall in the major axis and 0–5° in the minor axis, and product height is determined by surface area constancy.
Rule 11: If a process is the first process in top-part drawing, then a process is called bottoming and drawing coefficient applied should be in 0.64–0.7 with the body dimension of the major axis. After bottoming process, redrawing coefficient is used.
Rule 12: If a process is the last process in top-part drawing, then drawing coefficient applied must be 0.95.
Rule 13: If a process is first drawing, then R_p and R_d are C_{fd} (coefficient) times the thickness of the material blank (t_0).

$$R_p = C_{fp} t_0, \qquad R_d = C_{fd} t_0.$$

Here

$$C_{fp} = 6.0, \qquad C_{fd} = 4.0.$$

Rule 14: If a process is redrawing in cylindrical drawing, then R_p and R_d are C_{rd} times the reduction of the diameter.

$$R_p = \tfrac{1}{2}(D_{n-1} - D_n)C_{rd}, \qquad R_d = \tfrac{1}{2}(D_{n-1} - D_n)C_{rd}.$$

Here

$$1.5 < C_{rd} < 2.0, \qquad 1.0 < C_{rd} < 1.4.$$

D_n is the present cup diameter, D_{n-1} the previous cup diameter.
Rule 15: If a process is preform, then R_p and R_d are C_{pr} times the reduction of the diameter in the major and minor axes.

$$\text{For major axis}: \quad R_p = \tfrac{1}{2}(D_{cyl} - D_{mS})C_{pr}, \quad R_d = \tfrac{1}{2}(D_{cyl} - D_{mL})C_{dr}.$$

$$\text{For minor axis}: \quad R_p = \tfrac{1}{2}(D_{mL} - D_{mS})C_{pr}, \quad R_d = \tfrac{1}{2}(D_{cyl} - D_{mS})C_{dr}.$$

Here

$$1.0 < C_{pr} < 2.0, \qquad 1.5 < C_{dr} < 2.0.$$

D_{mL} is the body diameter of the major axis, D_{mS} the body dimension of the minor axis and D_{cyl} the diameter of the last cylindrical cup.
Rule 16: If a process is top-part drawing, then R_p and R_d are C_{td} times the reduction of the diameter.

$$R_p = \tfrac{1}{2}(D_{n-1} - D_n)C_{td}, \qquad R_d = \tfrac{1}{2}(D_{n-1} - D_n)C_{td}.$$

Here

$$0.8 < C_{td} < 1.5, \qquad 1.0 < C_{td} < 1.5.$$

D_n is the present cup diameter, D_{n-1} the previous cup diameter.
Rule 17: Draft of process sequence for elliptical shape products on Auto CAD represents side view of products in orthogonal axes. Description shows the geometry of the major axis on the left side and that of the minor axis on the right side.

3. Constitutions of the system

The input to the constructed process planning system is only a final product geometry whose modeling was performed on Auto CAD software along the major and minor axis of the appearance. It is convenient to construct, modify and extend with the aid of the modularity. Fig. 1 shows a module constitution in the system and Fig. 2 represents flow chart of the system. The system is composed of shape reading, recognition of the shape, three-dimensional modeling to calculate the surface area, blank design and process planning module. The following section will describe the function and characteristics of each module briefly.