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A study on the automated process planning system for cold forging of non-axisymmetric parts using FVM simulation

B.K. Lee[a], H.H. Kwon[b,*], H.Y. Cho[c]

[a]Mechanical Engineering of Graduate School, Chungbuk National University, Cheongju, Chungbuk 361-763, South Korea
[b]Mechanical Design Engineering, Daejin University, Pocheon, Kyeonggi-do 487-711, South Korea
[c]Department of Mechanical Engineering, Chungbuk National University, Cheongju, Chungbuk 361-763, South Korea

Abstract

A process planning system for cold forging of non-axisymmetric parts of comparatively simple shape was developed in this study. Programs for the system have been written with Visual LISP in AutoCAD. When a product is drawn on AutoCAD, it needs that the shape of the product is drawn with the solid line and the hidden line, and with the plane and front view, as well. At the plane, the system recognizes the external shape of non-axisymmetric portions—the number of the sides of the regular polygons and the radii of circles inscribing and circumscribing the polygon of n sides. At the front view, the system cognizes the diameter of axisymmetric portions and the height of the primitive geometries such as polygon, cylinder, cone, concave, convex, etc. And the system perceives that the list developed from the solid line must be formed by the operation of forward extrusion or upsetting, and that the list developed from the hidden line must be formed by the operation of backward extrusion. Suitability of the process planning was analyzed using SuperForge of FVM simulation package. The results of analysis showed good formability.

Keywords: Cold forging; Process planning; Non-axisymmetric parts; Visual LISP; AutoCAD; SuperForge; FVM

1. Introduction

Up to now, works on the process planning of cold forging have been mainly concentrated on the rotationally symmetric parts. But works on non-axisymmetric parts was not so actively going on, due to difficulties of shape cognition and expression, calculations of the process variables such as forming load, effective strain, effective stress. As for the study about this fields, Cho et al. [1] have studied about the computer-aided design system for the stepped asymmetric parts and Kim et al. [2] proposed a simple kinematically admissible velocity field to determine the final-stage extrusion load and the average extruded length in the square-die forward extrusion of non-axisymmetric bars from circular billets. Kim et al. [3] have developed UBET program to predict forging load, die-cavity filling, and the preform in non-axisymmetric forging. Lee et al. [4] have analyzed forward and backward extrusion of hexagonal and trochoidal-shaped wrench bolts using UBET.

The object of this study is to construct the automated process planning system of cold forging about relatively simple non-axisymmetric products such as special bolts being produced in the industries. To investigate formability and calculate the process variables such as forming load, and to verify suitability of operation sequences, a 3D metal forming simulation package—SuperForge was used. It has been reported that SuperForge provides results very close to those obtained from a validated 3D finite element analysis package—Deform 3D [5]. The finite volume technique used in SuperForge eliminates the remeshing problem that makes simulating a metal forming process with severe deformation so difficult. And the simulation time was saved considerably.

2. Structure and working principle of the system

2.1. Structure

Programs for the system have been written with Visual LISP and DCL (dialog control language) in the AutoCAD using a personal computer. The systems are composed of four main modules such as input module, shape cognition and expression module, material diameter determination module and process planning module such as Fig. 1. And

* Corresponding author.
E-mail address: hhkwon@daejin.ac.kr (H.H. Kwon).

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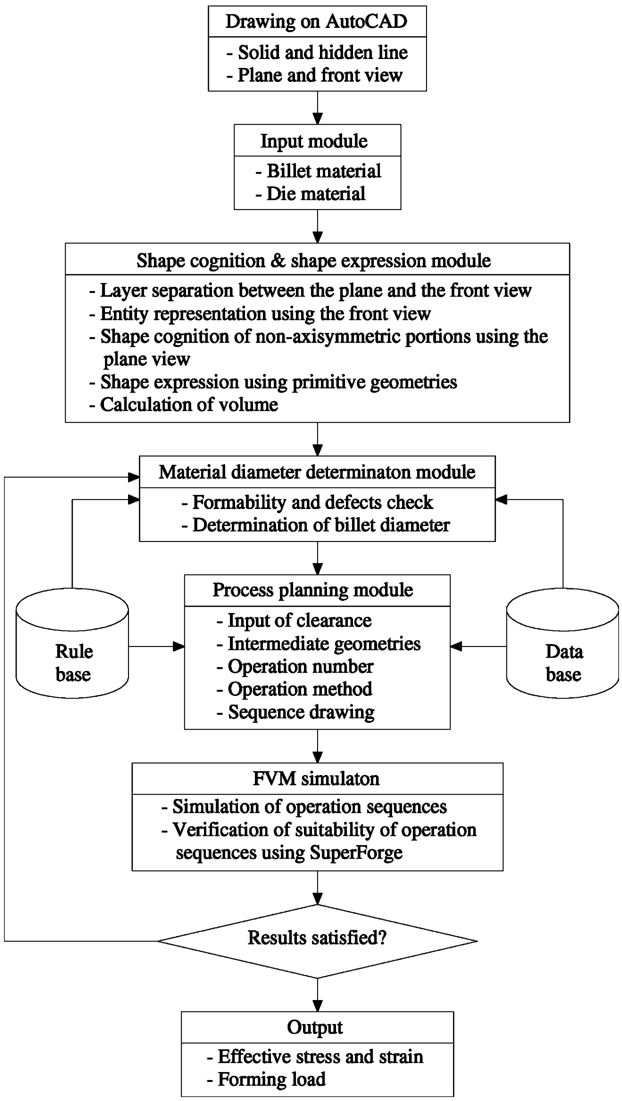

Fig. 1. Structure of the system.

suitability of operation sequences is investigated and process variables such forming load, effective strain, and effective stress are calculated by SuperForge.

2.2. Working principle

2.2.1. Input module

The user inputs or selects material of billet and die using DCL of Fig. 2. Then, properties and the values of formability limit of the materials are inputted from the database automatically.

2.2.2. Shape cognition and shape expression module

The drawing of a non-axisymmetric product is drawn with the solid and the hidden lines, and also with the plane and front view on AutoCAD such as Fig. 3. If the front view of drawing is selected using the mouse according to indication of DCL (Fig. 4), the layer of the plane view becomes layer 1 and the front view layer 2. The front view is divided into the solid line parts and the hidden line parts, and is represented by the aggregate of the entity representation lists such as ("Line" Sp Ep) and ("Arc" Sp Ep Cp). Here, Sp: start point (x_s, y_s, z_s), Ep: end point (x_e, y_e, z_e), Cp: center point of arc (x_c, y_c, z_c).

In the plane view, non-axisymmetric portions are perceived. A polygon is expressed by the list of punctual coordinates (x_i, y_i). The list of n sides of polygon consists of n points. In case of two or more polygons, each polygon lists are put together such as form (1). To each polygon, the radii of circles inscribing and circumscribing the polygon are found, and then expressed such as form (2). Accordingly, the system recognizes the numbers of regular polygons, the sides of each regular polygon, the radius of the circle circumscribing of n sides of a polygon, and correlation between the plane and the front view:

$$\text{p\_list} = (((x_{11}y_{11})(x_{21}y_{21})(x_{31}y_{31})\cdots) \times ((x_{12}y_{12})(x_{22}y_{22})(x_{32}y_{32})\cdots)\cdots) \quad (1)$$

$$\text{rl\_list} = ((r_{i1}r_{c1})(r_{i2}r_{c2})\cdots) \quad (2)$$

After the exclusion of the horizontal lines at the aggregate of the entity representation lists, the right side only is selected on the basis of the center line, then line up in ascending powers according to the size of y values, and the lists of polygon are found using (1) and (2) of the shape cognition lists. So, the results are expressed by the primitive geometries such as cylinder, polygon, cone, concave, convex, pol-convex (in case of filleting edge of polygon pillar or bottom edge of polygon hollow), pol-concave (in case of filleting connection portion when polygon pillar is connected with another primitive geometry, or top edge of polygon hollow). The shape expression lists are indicated such as ("shape", h, d_1, d_2, r_n). Here, shape is the primitive geometry, h the height of each shape, d_1 the diameter of lower end portion of shape (in case of polygon, the diameter of the circle inscribing the polygon), d_2 the diameter of upper end portion of shape (in case of polygon, the diameter of the circle circumscribing the polygon), and r_n the radius of arc (in case of polygon, the number of sides of each regular polygon). And the system perceives that the list developed from the solid line must be formed by the operation of forward extrusion or upsetting, and that the list developed from the hidden line must be formed by the operation of backward extrusion.

2.2.3. Material diameter determination module

In this module, the minimum and maximum diameter of the object are automatically presented and the user inputs the diameter using DCL (Fig. 5). And using the list of the diameters of cylinder or polygon (in case of polygon, the diameter of the circle calculated to the area after converting the area of the regular polygon into the area of a circle), upset ratios and effective strains are calculated to the inputted diameter, and the system investigates if each satisfies the rules. If the results do not satisfy the rules, the systems give an order to choose billet diameter again. Finally, the billet diameter is determined.