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Development of an integrated computer-aided process planning system for press working products

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Abstract

This paper describes research work in developing an automated computer-aided process planning system for a hot forging or blanking product by press working. The computer-aided process planning system written in AutoLISP on AutoCAD using a personal computer and in I-DEAS Drafting Programming Language on the I-DEAS Master Series Drafting with workstation in hot forging and blanking requires many kinds of technical and empirical skills. An approach to the computer-aided process planning system is based on knowledge-based rules and a process knowledge base consisting of design rules is built. Based on the investigation and collection of knowledge of the processes, the methodology adopted to develop this system is elaborated in this paper. This integrated computer-aided process planning system is composed of two main modules: hot forging and blanking modules. It is designed by considering several factors, such as the complexities of the blank geometry, the punch and die profiles, the availability of press equipment, and standard parts. Results obtained using the modules enable the designer and manufacturer of forging or blanking dies to be more efficient in this field.

Keywords: Blanking; Hot forging; Knowledge-based rules

1. Introduction

Worldwide mechanical communications, electronics, and light industries have been booming for a few decades at an even accelerating speed. This is partly due not only to the advances in basic sciences and technologies but also to the development of metal forming process supported equipment and die making technologies. Among others, wide applications of computer-aided process planning in hot forging or blanking will result in the mass production of high-quality metal parts at a low cost and high productivity. Metal forming, by which parts with a desired shape are manufactured from metal or sheet metal using a punch and a die, especially needs this kind of standardization for the compatibility and accuracy of components. However, mainly the experience and intuitional decisions of skillful engineers have accomplished metal forming with press working operation. Those skillful engineers also manufacture parts of the die and punch according to such a process planning drawing. In order to solve this problem, considerable interests are focused on reducing the design time required for designing and manufacturing. Thus it is necessary to develop computer-aided tools for automated process planning and die design to further augment the competitiveness of industry. The core of these tools is an integrated information model, which captures the complete information needed by various applications such as feasibility analysis, process planning, and process simulation. Research have been reported on the automation of computer-aided process planning and manufacturing for the designed product by formalizing the experience of skillful engineers [1–3]. Nakahara et al. [4] introduced a system for a progressive die design. Also recently Choi et al. [5,6] developed a compact and practical CAD system for the blanking or piecing of irregular shaped sheet metal products and stator and rotor parts.

2. Structure and working principle for the integrated computer-aided process planning system

2.1. Structure of the integrated computer-aided process planning system

The system is composed of hot forging and blanking modules and each module has four and five sub-modules. Processes are accomplished without interruption, as each module holds the rules and data in common. The system is easy to use, as the dialogues are user-friendly with

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appropriate promoting statements by using DCL mode for the various data required.

2.2. Operating principle of integrated computer-aided process planning system

1. *Entity representation*:
   - *Line and arc representation*:

   $$(0.0\,(\mathrm{Sp\,Ep})\,(\mathrm{Sp\,Ep})\,(\mathrm{Sp\,Ep})\cdots(\mathrm{Sp\,Ep\,Cp})\times(\mathrm{Sp\,Ep\,Cp})\cdots)$$

   - *Circle representation*:

   $$(0.0\,(\mathrm{Cp}\,R)\,(\mathrm{Cp}\,R)\,(\mathrm{Cp}\,R)\cdots)$$

   where (Sp Ep) is a line, (Sp Ep Cp) a arc, (Cp R) the circle, Sp($x_s\ y_s\ z_s$) a start point, Ep($x_e\ y_e\ z_e$) a end point, Cp($x_c\ y_c\ z_c$) a center point in the case of arc or circle, and R a radius of circle. In order to use these data in each sub-module, the system organizes closed loops for the entities composed of lines and arcs in the clockwise direction.

$$(0.0\,(P_1\,P_2)\,(P_2\,P_3\,P_{C1})\,(P_3\,P_4)\cdots(P_{n-1}\,P_n\,P_{cn})\,(P_n\,P_1))$$
$$((q_1\,q_2)\,(q_2\,q_3)\,(q_3\,q_4\,q_{c1})\cdots(q_{n-1}\,q_n\,q_{cn})\,(q_n\,q_1))$$

   In the $(P_{n-1}\,P_n\,P_{cn})$ $(P_n\ P_1)$, where P_n is not only a end point of $(P_{n-1}\,P_n\,P_{cn})$ but also a start point of $(P_n\ P_1)$ and P_{cn} is a center point of arc. In $P_1(x_1\ y_1\ z_1)$, x_1 is the least x value in the close loop of "P" type. Based on the P_1 base point, the closed loop of "P" type is recognized as the clockwise direction.
2. *Feature representation*: Representation of the geometry database, "feature representation", which can be easily used to recognize the geometrical features of a section, is as follows:
   - Presentation of basic shape:

$$(\mathrm{FBsType}\,(\mathrm{PrG_1\,Hei_1\,DaL_1\,Ri_1\,Ro_1\,Rcv_1})$$
$$(\mathrm{PrG_2\,Hei_2\,DaU_2\,Ri_2\,Ro_2\,Rcv_2})$$
$$)$$

   where "FBsType" shows whether the shape of a part has inside steps or outside steps and "PrG" is a list of basic shape. Hei, DaU, DaL, Ri, Ro and Rcv are a height, a upper diameter, a lower diameter, fillet/corner radius and concave/convex radius.

3. Rules of integrated computer-aided process planning system

The integrated computer-aided process planning system, uses organized rules and a database extracted from plasticity theories, relevant references, and the empirical know-how of experts in industries as process variables for hot forging and blanking. Rules organizing empirical know-how and guide for the design are based on tree decision which takes the form of "IF (conditions) THEN (actions)". According to the conditions, the system calculates the action part and the results of the action part are inputted to the next condition.

4. Application and results of the integrated computer-aided process planning system

4.1. Application to the hot forging module

When an axisymmetric product as shown in Fig. 1 is applied to the forging design sub-module of the hot forging module, the results calculated in the sub-module are considered here. An axisymmetric sample with the maximum diameter of 100.0 mm, which has ribs at the end and the middle sections, is taken. In order to convert a machined part into a forging part, input items of the forging design sub-module are required as shown in Table 1. The mechanical properties of the input material are obtained from the database. If undercuts exist in the section of the sample, the shape drawing is modified. The finisher die design sub-module checks the forming feasibility of the billet as one stage in the final die and outputs process variables such as the maximum load, stress distribution, and flow model. In the case of the infeasibility of forming in one stage due to defects, or the impossibility of mass production, the blocker design sub-module carries out the blocker process, which improves the tool life reducing the wear of the fillet part of die. After the blocker design sub-module checks the forming feasibility for the forging product, Al 7075, the results of the sub-module show that the blocker process is required according to the hot forging design rules, as the shape difficulty factor of the forging product is 1.783. Therefore, the results of a process planning drawing generated in the finisher die design sub-module are shown in Fig. 2. The

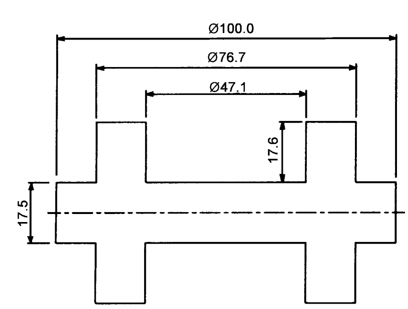

Fig. 1. A sample product for use with the hot forging module.

Table 1
Input items for carrying out forging design sub-module

Tolerances and allowances	
Length and width tolerance	0.462
Die wear	0.616
Mismatch	0.406
Die closure	0.787
Straightness	0.462