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A CAD/CAM system for deep drawing dies in a simple-action press

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Abstract

In this study, a CAD/CAM system for axisymmetric deep drawing processes has been developed. A knowledge-based approach is employed for the system. Under the environment of the CAD/CAM software of Personal Designer, the system has been written in UPL (User Programming Language). The geometry of the intermediate and the final object in deep drawing processes, including processes parameters, are inputs for the CAD/CAM system. The input data can be obtained from the results of Pro_Deep. The parts drawing of die sets for each process is generated in the tool design module of the CAD/CAM system. Also, the die assembly drawings can be obtained. NC commands for the machining of the part can be generated in the developed CAD/CAM system.

Keywords: CAD/CAM system; Tool design; Automatic modeling; Blanking die-set; Deep drawing die-set; Rules base; Tool path generation

1. Introduction

Amongst the methods of sheet metal forming, deep drawing is that most commonly used. However, the traditional process design of deep drawing is performed by human experts with their empirical knowledge. In recent years, some computer-aided process and die design systems based on the empirical knowledge of the field experts have been developed for axisymmetric deep drawing products. Eshel et al. [1] developed the Automatic Generation of Forming Process Outlines (AGFPO) system for axisymmetric and monotone parts, produced by deep drawing. They suggested G&TR (Generate and Test and Rectify) strategy for the process planning of axisymmetric deep drawing products. The system relies only on experience-based die-design guidelines for its process-sequence design. Tisza's work [2] describes a modular CAD/CAM system, in process, for developing deep drawing process sequences and designing tools for the manufacture of sheet-metal components having axisymmetric and rectangular cross-sections. Sitaraman et al. [3] developed a hybrid computer-aided engineering (CAE) system for automatic process sequence design for the manufacture of axisymmetric sheet-metal components. Two main components of the hybrid CAE system are either KBS or expert system modules and a process-modeling analysis module. Xiao et al. [4] set up the expert system, DPES, in designing axisymmetric deep drawing parts. The system can be suited to the process planning of general drawing and to the strip progressive drawing of axisymmetric parts. Zhu et al. [5] developed an expert system, PAD-ES, for the process planning of axisymmetric deep drawing. The whole program was coded in C language. Tisza [6] presented new results from the development of Knowledge Based Expert Systems for metal forming applications. Altan et al. [7] developed the Axisymmetric Sequence Forming Expert System (ASFEX) for axisymmetric parts, produced by deep drawing. The process design systems [1,3–7] were developed using the G&TR strategy that was proposed by Eshel et al. [1], and the tool design and forming analysis were performed.

In this study, a CAD/CAM system for axisymmetric deep drawing processes has been developed. The inputs

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of the CAD/CAM system are the results of Pro_Deep [8], which was developed by the authors. The system, Pro_Deep, is the process design of a deep drawing system for axisymmetric products [9]. A knowledge-based approach is employed for the system. Under the environment of CAD/CAM software of Personal Designer, the system has been written in UPL (User Programming Language). The geometry of the intermediate and the final object in deep drawing processes, including process parameters, is the input for the CAD/CAM system. The input data can be obtained from the results of Pro_Deep. The part drawings of die sets for each process are generated in the tool design module of the CAD/CAM system. Also, the die assembly drawings can be obtained. NC commands for the machining of the part can be generated in the developed CAD/CAM system. The system can be applied to a blanking die set and deep drawing in a simple-action press.

2. The process design system and CAD/CAM system

The block diagram of the CAD/CAM system for the deep drawing process can be seen in Fig. 1. The input to the process design system, Pro_Deep, is the drawing of the final sheet metal object geometry, the output resulting from the above input being the drawing of process sequence with the intermediate object geometry. Also, the process parameters, such as drawing load, blank-holding force, clearance and cup-drawing coefficients, are determined. The results of the CAD system, Pro_Deep, are used for the design of die sets in the CAD/CAM system. The die sets of the system include three cases, which are a blanking die set, a first drawing die set and redrawing die set. The blanking die set is designed for circular blanking in a simple-action press. Also, the drawing die sets are designed for axisymmetric deep drawing in simple-action press. The drawing die sets are of the knock-out type with a blank holder. The structure of the die sets and the parts of the tool are determined. Then, according to the design rules, the dimensions of the parts are determined. The simulation module of the forming, which can be seen in Fig. 1, is expected to be used for verification of the deep drawing process. The module has not been developed for the system. The part drawings are produced for each elements of tool. The construction drawing of the die set and NC machining data of the tool elements can be obtained from Personal Designer.

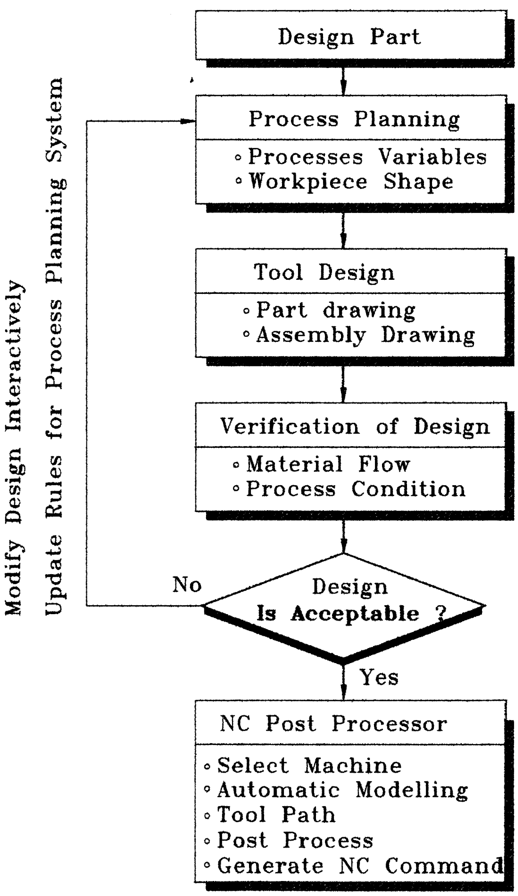

Fig. 1. CAD/CAM/CAE system for the deep drawing process.

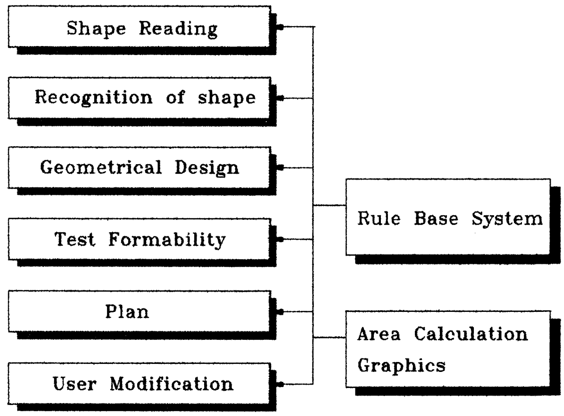

Fig. 2. Block diagram of the Pro_Deep system.

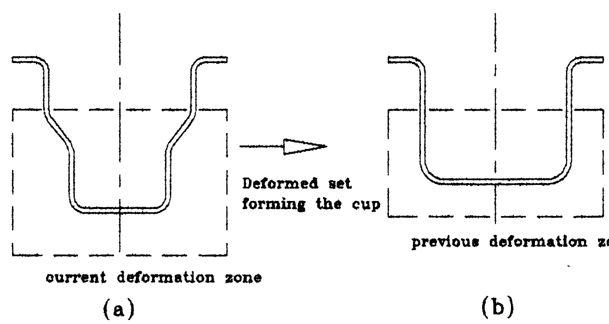

Fig. 3. Generation of intermediate stages in the geometrical design module: (a) the final product; (b) the intermediate shape of the cup.

2.1. Deep drawing process design system for axisymmetric products, Pro_Deep [8]

Using G&TR strategy, the block diagram of the CAD system, Pro_Deep, can be seen in Fig. 2. The developed CAD system, Pro_Deep is composed of four main modules, i.e. input, geometrical design, test & rectification, and user modification.

The input to the Pro_Deep is the final sheet-metal object geometry for which a process sequence needs to be designed. One input format is a drawing file, DWG, on the AutoCAD system. Other formats of input file, which can be translated into a DWG file on the AutoCAD system, such as DXF and IGES, are also usable. The drawing file can be read by the input module.

The geometrical design module creates automatically the initial hypothesis of the process sequence in the reverse or backwards direction, starting from the final

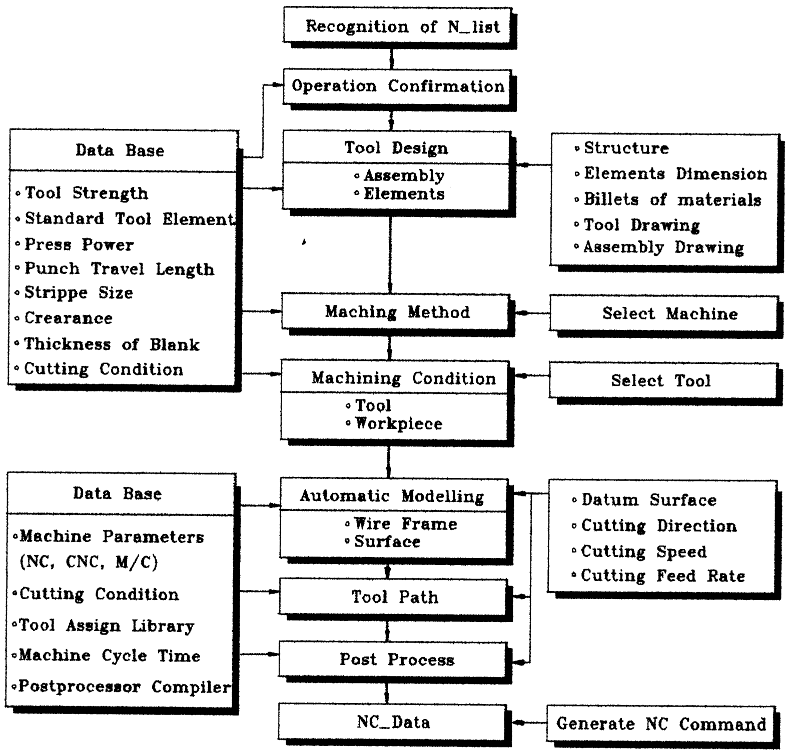

Fig. 4. Block diagram of the CAD/CAM system for deep drawing dies.

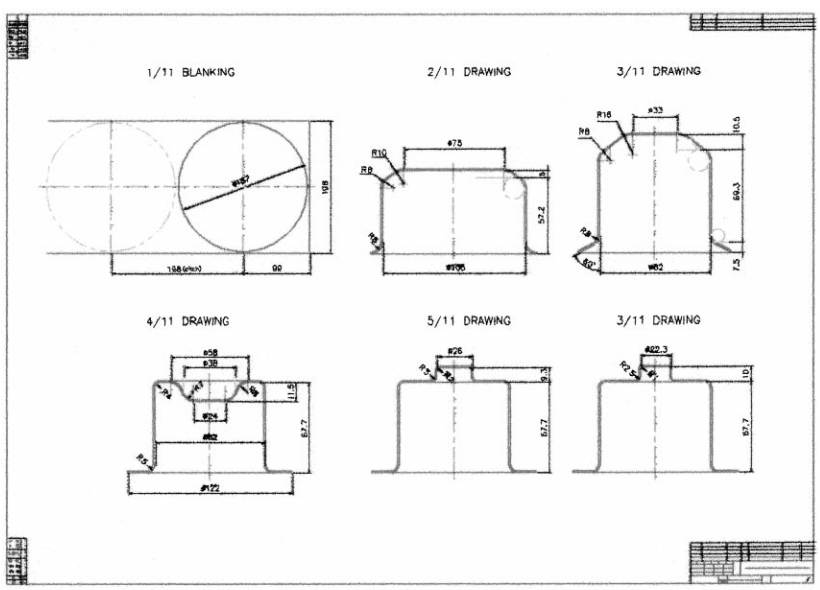

Fig. 5. Sequence drawing for the deep drawing part of the ‘motor housing’: industrial practice.

Process	1	2	3	4	5
Draw Ratio	0.46	0.92	0.51	0.70	0.88
Clearance(mm)	1.72	1.64	1.56	1.44	1.26
P.Force(ton)	10.55	9.04	6.73	4.07	2.83
B.H Force(ton)	2.43	2.08	1.55	0.94	0.65

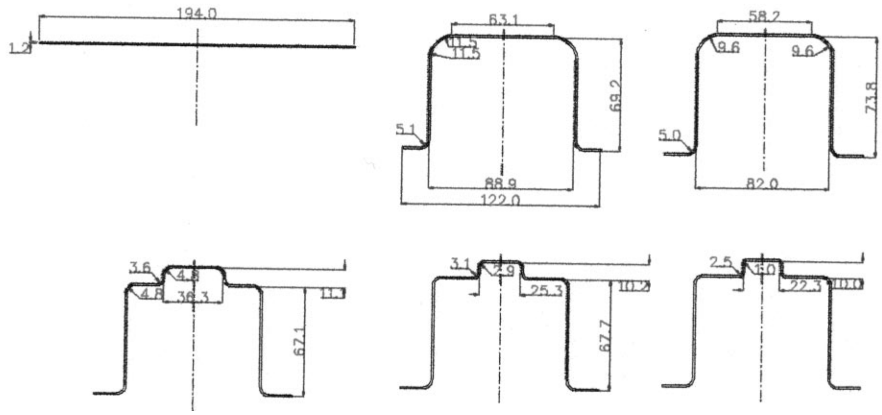

Fig. 6. Sequence drawing for the deep drawing part of the 'motor housing': the output of Pro_Deep.

object geometry based only on the geometrical features of the cup.

A current deformation zone can be determined by the geometrical features of the cup. The shape of the previous deformed zone is a straight and vertical non-flanged cup. The dimensions of the cup are determined by the incompressibility of the sheet metal. Examples of the current deformation zone and the previous deformation zone are shown in Fig. 3. This procedure will be performed recursively until the previous shape is a flat circular blank.

The process sequence obtained through the geometrical design module may not be practical and feasible. The process sequence takes the formability of the material into consideration. To test the formability of the process sequence process parameters, such as the drawing ratio, the redrawing ratio and the flange wall thickness ratio are calculated and compared with limiting values, which are empirical and theoretical data. The methods for determining the limiting value of the drawing ratio or cup drawing coefficient are elementary calculation methods [9,10] and the corrected optimal drawing ratio [1].

The process sequence will be rectified if a formability violation is predicted. New intermediate cups are added to the process sequence. The shape and dimensions are determined by the design rules of Pro_Deep, the procedures of generation of the intermediate stage being summarized in [7]. To avoid fracture and wrinkling of the sheet metal, the die profile radius and the punch profile radius should be determined. The dimensions and shape of the punch profile radius and die profile radius are rectified for the prevention of excessive thinning of the material and of the formation of annular marks on the cylindrical surface of the component, caused by bending and straightening of the material in successive operations.

The CAD system, Pro_Deep, has a user modification module. The results of Pro_Deep can be modified easily by a skilled designer. Then, the empirical knowledge of a skilled user is presented in the results. The intermediate object geometry can be modified into a geometry that has newly inputted process parameters, such as the drawing ratio, the redrawing ratio, the punch profile radius, and the die profile radius, by the users modification module.

2.2. *CAD/CAM system for tool elements*

The CAD/CAM system for tool elements of deep drawing sets is shown in Fig. 4. The CAD/CAM system has been developed under the environment of CAD/CAM software, Personal Designer [11], and is written in UPL. The commands of Personal Designer are programmed by using UPL. The commands are wholly related to 3-dimensional modeling (wire frame, surface and solid modeling), tool path generation and post process, etc.

The results of Pro_Deep [8] are the drawing of the process sequence with the intermediate object geometry and the drawing of the process parameters. The data of the geometry and the process parameters have been used for the input to the CAD/CAM. The drawings of tool elements for the deep drawing and blanking are designed automatically by the system. The construction of the deep drawing and blanking die set are easily obtained by using the drawing of the tool elements. The dimensions of the parts are used for the modeling data in Personal Designer.

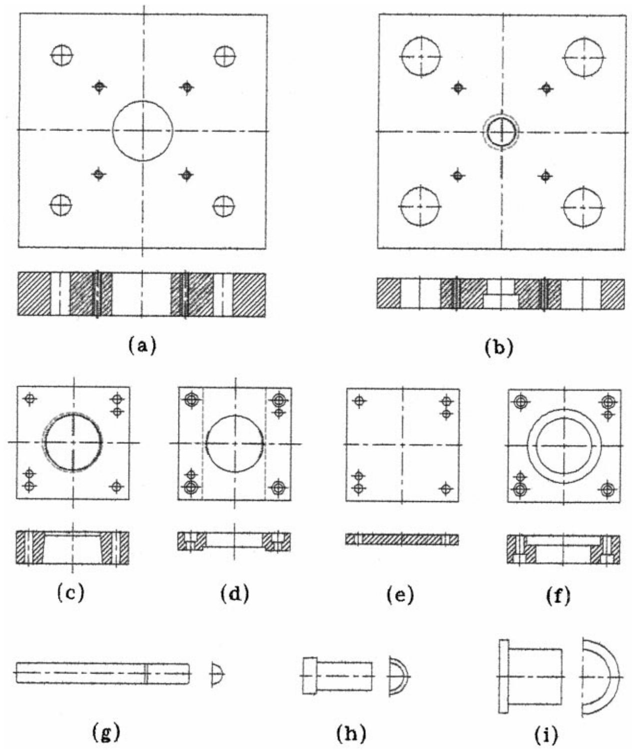

Fig. 7. Parts drawings for the blanking die: (a) lower holder; (b) upper holder; (c) die; (d) stripper; (e) backing plate; (f) punch holder; (g) guide post; (h) shank; (i) punch.

Then, the tool path generation and NC commands for the machining of the tool elements can be obtained from the developed CAD/CAM system in the software of Personal Designer. NC data can be generated according to the machining rule base, these rules having been made from the data-handbook [12].

3. Design rule of the CAD/CAM system

In this paper, the CAD/CAM system has been developed for tool elements of the blanking process for a circular blank and deep drawing processes in a simple-action press. The design rules of the tool elements for deep drawing have been formulated by one of the present authors [13]. For the die set of a circular blanking, the design rules are summarized elsewhere [14,15].

In this paper, the design rules are used. The shape of the tool elements have been previously determined for the circular blanking [15], first drawing [13], and re-drawing [13] processes. The rules used are not shown in this paper as they are quite lengthy and available in Refs. [13,15,16].

According to the input data, the dimension of the tool elements for each process can be determined using the design rules. The modeling of the elements is first completed, then the NC data and tool path are generated according to the machining rule base [12].

The procedure of the CAD/CAM system is simple because the system is a prototype for the CAD/CAD system for the deep drawing process.

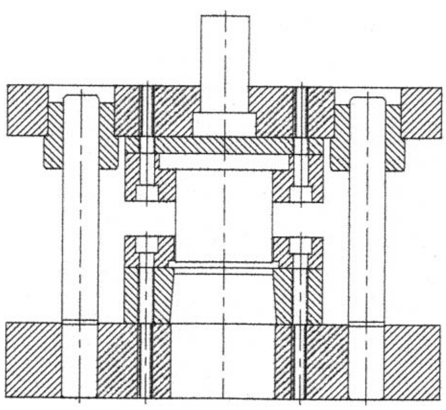

Fig. 8. The construction of the blanking die.

4. Application of the CAD/CAM system

The developed CAD/CAM system has been applied to industrial practice. Fig. 5 shows the drawing process sequence for the production of a 'motor housing'. The

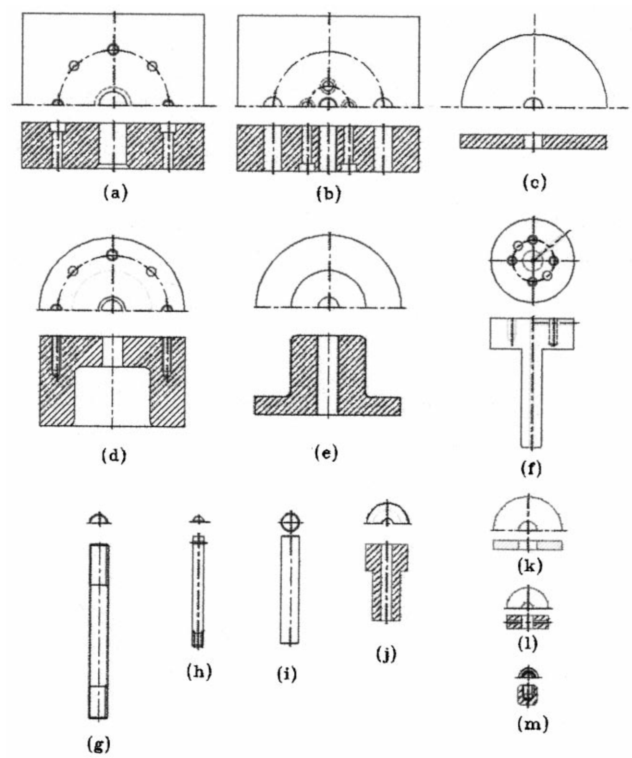

Fig. 9. Part drawings for the final deep drawing: (a) die; (b) punch; (c) blank holder; (d) knockout pad; (e) cushion pin; (f) plate, cushion pin; (g) plate, spring supporter; (h) bolt stopper; (i) stopper pin; (j) shank; (k) punch holder; (l) rod, spring bolt; (m) spring; (n) die holder; (o) nut; (p) knockout bolt.

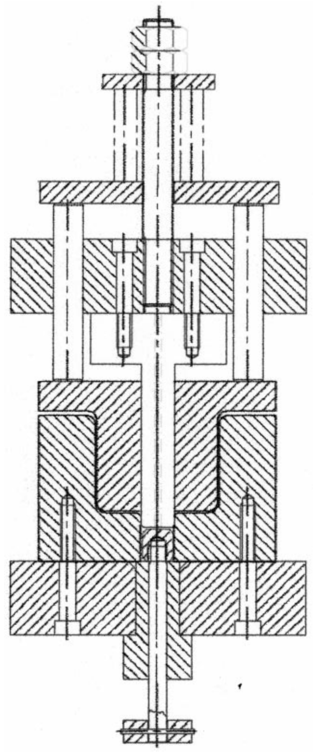

Fig. 10. The construction of the final deep drawing die.

process sequence drawing obtained by using Pro_Deep, can be seen in Fig. 6 [8].

The following results have been obtained using the developed CAD/CAM system. The inputs of the CAD/CAM system are the results of Pro_Deep. The sequence drawing for the deep drawing of this part are shown in Fig. 6, whilst the drawings of the tool elements can be seen in Fig. 7. The standard elements of the bolt and the guiding bush are neglected. Thus, the tool elements in Fig. 7 may be produced by machining.

Fig. 8 is the construction of the blanking die, which can be obtained easily using Fig. 7.

The drawings of the tool elements for redrawing in the final process, Fig. 6, can be seen in Fig. 9. The tool elements in Fig. 9 may be produced by machining. For the elements, the NC data can be generated in Personal Designer. Fig. 10 shows the construction of the redrawing die, which can be obtained easily using Fig. 9.

In the developed CAD/CAM system, the dimensions of the tool elements for the blanking shown in Fig. 7, and first drawing and redrawing shown in Fig. 9, are determined according to the design rules. The shape of the tool elements have been determined previously. These points of the system should be improved: however, presently the system is only a prototype for a CAD/CAM system of a deep drawing process.

In CNC machining, the tool path of the die for the final deep drawing process can be seen in Fig. 11 in which (a) is drilling with a CNC lathe; (b) is roughing with a CNC lathe; and (c) is finish with a CNC lathe.

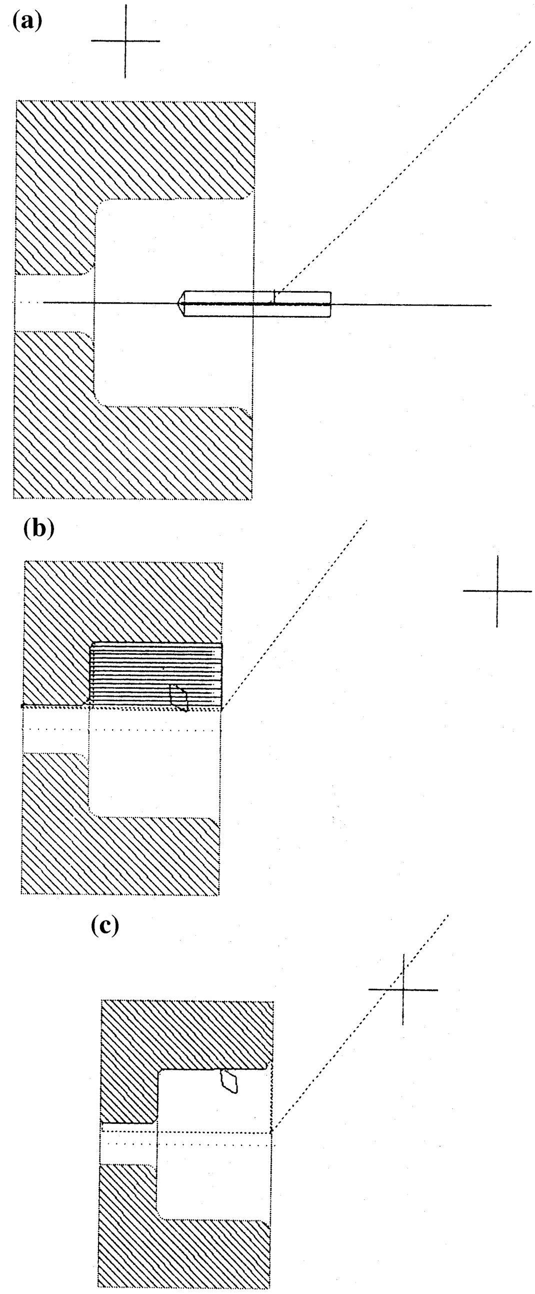

Fig. 11. The generated tool path of the die for the final deep drawing process: (a) drilling with a CNC Lathe; (b) roughing with a CNC Lathe; (c) finishing with a CNC Lathe.

The generated tool path of die holder for the final deep drawing process can be seen in Fig. 12. The 3-dimensional machining data can be obtained because the shape was determined previously [13,15].

5. Conclusion

In this paper, the CAD/CAM system has been devel-

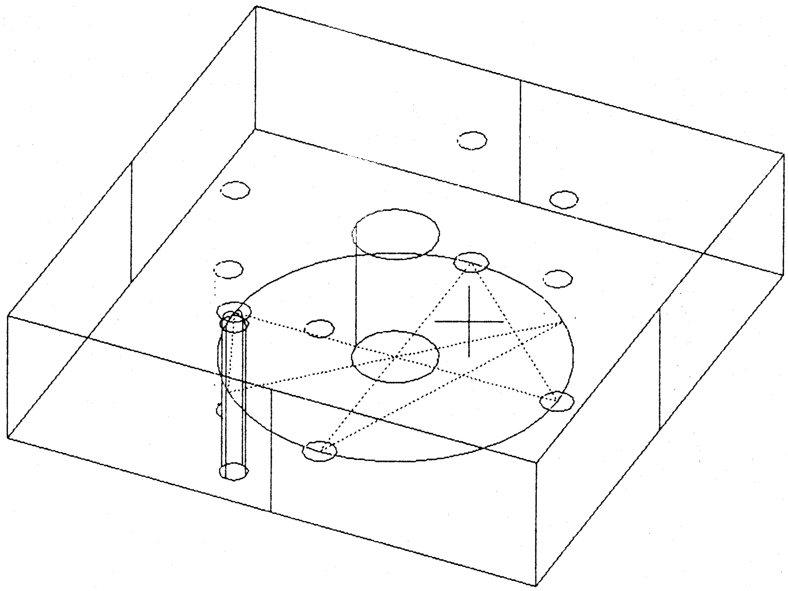

Fig. 12. The generated tool path of the die holder for the final deep drawing process (drilling and reaming using a Machining Center).

oped for the design and machining of tool elements in the deep drawing process. The CAD/CAM system has been developed under the environment of CAD/CAM software, Personal Designer [11], and written in UPL. The commands of Personal Designer are programmed by using UPL. The used commands are wholly related to 3-dimensional modeling (wire frame, surface and solid modeling), tool path generation and post process, etc. The shapes of the tool elements have been determined previously for the circular blanking [15], first drawing [13] and redrawing [13] processes, in simple-action press. Because the system is a prototype at present, the system will be developed to include the various aspects of tool design in sheet metal forming. According to the input data, the dimensions of the tool elements for each process can be determined using the design rules. After the modeling of the element has been completed, the NC data and tool path can be generated according to the machining rule base [12]. The procedure of the CAD/CAM system is simple because the system is a prototype for the CAD/CAD system for a deep drawing process. The tool configuration of each station can be used to verify the forming process by using FEM analysis, but the work has not been implemented in the current version. The output of the system will be improved for analysis in the next version.

Acknowledgements

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