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AN EXPERT SYSTEM FOR DESIGN OF DIE BLOCK OF DEEP DRAWING DIE

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ABSTRACT

In this research an expert system is developed for design of die block of deep drawing die. The system is developed using production rule based expert system approach of Artificial Intelligence (AI).The proposed system consists of two modules namely DBLCK and DBLCKMOD. The first module is developed for selection of proper size of die block and the second module is constructed for modeling of die block in the drawing editor of AutoCAD. Modules are coded in AutoLISP and visual basic 6.0 language and interfaced with AutoCAD software. The proposed system is capable to automate the design and modeling of die block of deep drawing die. As the system can be easily implemented on a PC with AutoCAD software, therefore its low cost of implementation makes it affordable for small scale sheet metal industries.

Keywords: Expert System, Die Block, Deep Drawing Die and AutoCAD.

1. Introduction

The process of design of deep drawing die is complex and highly specialized. Quality, reliability, cost, and functionality of deep drawn parts largely depend on design of deep drawing die. The diverse nature of deep drawing products demands a high level of theoretical and practical knowledge on the part of die designers. Traditionally, the design process of deep drawing die is manual, tedious, time consuming and error-prone which results in high cost and long manufacturing lead time of deep drawn parts [1]. Die block of deep drawing die is the real operating component and account for a large portion in the entire design process of die. The complexity, cost and durability of a die depend largely on the design of die block. Thus, the design of die block is critical to a die designer in terms of the design quality and productivity. Today, commercial softwares such as SOLIDEDGE, PRO-E, CATIA, IDEAS, UG etc. are popular in industries for CAD modeling. But most of the important decisions, such as the assessment of formability, development of strip layout, design of die components and modeling of deep drawing die are still made interactively by experienced die designers. These CAD softwares have failed to provide sufficient design knowledge to the users, which is of great help in most design tasks [2]. Therefore skilled and experienced die designers are required to operate these systems and finally to take appropriate decisions. Also because of high cost associated with these softwares, there are not affordable by small scale industries especially in developing countries [3]. Therefore there is urgent need for development of an expert system for design of deep drawing die. This system must be user interactive, have low cost of implementation, and capable to perform design and modeling of deep drawing die quickly, automatically and efficiently.

In recent years some expert systems or knowledge based systems (KBS) have been reported in literature for design of dies and molds. Cheok et al. [4] made an attempt to automate progressive metal stamping die design through KBS approach. Esche et al. [5] developed Axisymmetric Sequence Forming Expert System (ASFEX) for multi step forming of round cups. Park et al. [6] developed a prototype CAD/CAM system for axisymmetric deep drawing processes in simple action press. Lee et al. [7] proposed a parametric computer-aided tool design system for cold forging using AutoLISP language. Myung and Han [8] proposed a parametric design expert system combined with available CAD system for parametric design of mechanical products in a 3D environment. Kong et al. [9] developed a Windows-native 3D plastic injection mold design system based on SolidWorks using Visual C++. Sutt et al. [10] proposed a design environment for design of progressive cutting dies using mid-range level CAD package. Vosniakos et al. [11] used ‘logic programming’ to plan the process in sheet forming with progressive dies. The product category targeted was U-

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shaped with bending and cutting operation predominantly. Nahm and Ishikawa [12] combined set-based design practice with parametric modeling technique widely used in most 3D-CAD systems to handle the uncertainties that are intrinsic at early stages of the design. Roh and Lee [13] proposed a hull structural modeling system for ship design, which was developed using C++ and built on top of 3D CAD software. Lin et al. [14] developed a KBS for design of drawing die on Pro/E CAD software platform. Tsai et al. [15] used knowledge based engineering (KBE) methodology to automate the process planning and die design in automotive panel production. Lin and Kuo [16] presented a method to explore multi-objective optimization in the structural design of ribs for drawing dies by combining finite element analysis and fuzzy-based Taguchi method. Potocnik et al. [17] developed a KBS for supporting the design of a plate-press. The system is implemented on CATIA V5 CAD-system. The proposed system is still prototype in nature.

Review of the published literature revels that few researchers have applied efforts for development of automated systems for deep drawing die. But most of the systems developed are having limited functionalities. They can handle specific parts with relatively simple geometry. In the present work, an attempt is made to develop an expert system for design of die block of deep drawing die. The proposed system is user interactive, flexible and can be easily implemented on a PC with AutoCAD software.

2. Guidelines for Design of Die Block

Die block is one of the major components of a deep drawing die. It contains a die cavity and fastened on lower shoes. Some basic guidelines are generally used in industries for design of die block of deep drawing die. A sample of these guidelines is given as under. The die area on the lower shoes should be at least 6.35 mm larger all around the die block.

(i) Ears should be provided on the die block to fasten it to the bolster plate of press with help of T-bolts.
(ii) Die block should be made of superior quality steel since it has cutting edges and it is subjected to extreme pressure and wear condition.
(iii) While deciding about the thickness of die block, consideration must be given to strength required to resist the cutting process, and the type of thickness of the material being cut.
(iv) The side wall of the die block opening should be provided with sufficient relief of tapers' so that blank drops clear through it.
(v) There should be a minimum of 32 mm margin all around the opening of die block.
(vi) Dowel pins must be used to fasten die block on lower shoes

Keeping in view of the above basic guidelines and recommendations, an expert system is developed for design of die block of deep drawing die.

3. Proposed Expert System for Design of Die Block

The procedure, execution and sample run of proposed expert system are described as under.

3.1 Procedure for development of proposed system

The procedural steps used for development of proposed system involve knowledge acquisition, framing of production rules, verification of production rules, sequencing of rules, identification of computer language and hardware, construction of knowledge base, choice of search strategy and preparation of user interference [18]. The heuristic knowledge and facts gathered for development of knowledge base of the proposed system includes knowledge of domain experts extracted through online and offline consultation, and depth in study of published literature (industrial brochures, research papers, die design hand books etc.). The knowledge so gathered was systematically classified, analyzed and then represented using production rules of 'IF- THEN' variety. The production rules so framed were verified from a team of die design experts and tool manufacturers. The proposed system has more than 300 production rules. A sample of production rules incorporated in proposed system is given in Table 1. Production rules in each module of the proposed system are arranged in a structured manner. This arrangement allows insertion of new production rules even by relatively less trained knowledge engineer. The inference engine is used to link production rules and knowledge base of modules through forward chaining search strategy. The production rules incorporated in the modules have been coded in AutoLISP language. Inference mechanisms search through the knowledge base to arrive at decisions. In the proposed system forward chaining search strategy is used to arrive at the conclusion. Forward chaining is a good technique when all on most paths from any one of much initial or intermediate state converges at once or a few goal states. User interface is created using Visual Basic 6.0 language and interfaced with AutoCAD software. It allows the users to input part details and also to display drawings in the drawing editor of AutoCAD.

Table1: A Sample of Production Rules Include in the Proposed System

S. No	IF	Then
1	Material= mild steel; and Blank perimeter ≥ 250 mm; and Die material = tool steel	Select thickness of die block = 35 mm
2	Blank perimeter ≤ 75 mm; and Die material = tool steel	Select thickness of die block = 19 mm
3	Sheet thickness ≤ 1.6 mm; and Sharp edge does not exist in the edge perpendicular to the moving direction of the sheet	Set width of die block in mm = (Sheet width + 72)
4	Sheet thickness > 3.2 mm; and Sheet thickness ≤ 4.5 mm; and Sharp edge does not exist in the edge perpendicular to the moving direction of the sheet	Select width of die block in mm = (Sheet width + 100)
5	Sheet thickness > 1.6 mm; and Sheet thickness ≤ 3.2 mm; and Sharp edge exists in the edge parallel to the moving direction of the sheet	Select length of die block in mm = (Strip-layout length in mm + 50)
6	Sheet thickness > 1.6 mm; and Sheet thickness ≤ 3.2 mm; and Sharp edge does not exists in the edge parallel to the moving direction of the sheet	Select length of die block in mm = (Strip-layout length in mm + 36)
7	Sheet thickness ≤ 1.6 mm; and Sharp edge does not exist in the edge parallel to the moving direction of the sheet	Set length of die block in mm = (Strip-layout length in mm + 30)

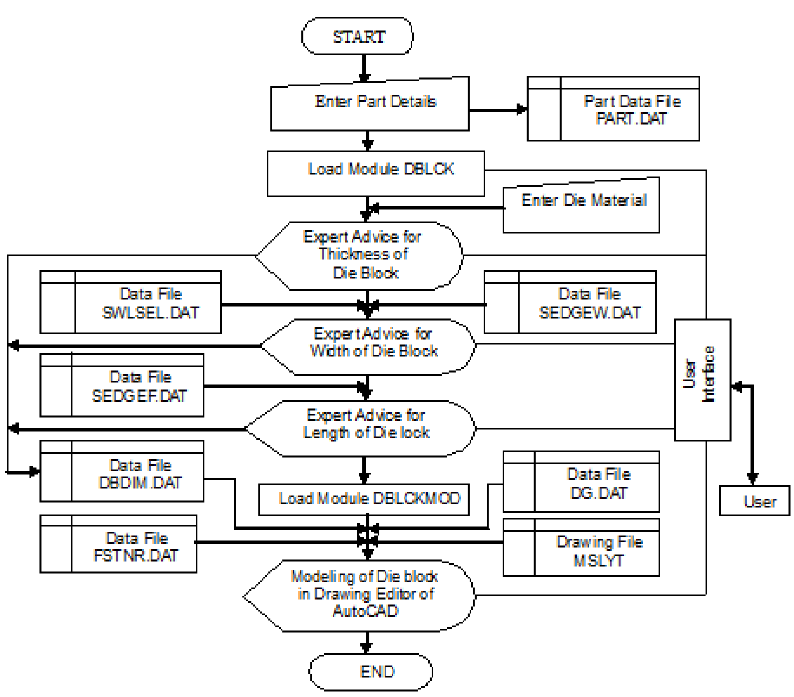

Fig. 1 Execution of Proposed System

3.2 Execution of the proposed system

The proposed system consists of two modules namely DBLCK and DBLCKMOD. Execution of the proposed system is demonstrated through a flow chart as shown in Fig. 1. A brief description of each module is given as under.

3.2.1 Module DBLCK

This module has been developed to impart expert advices to the user for selection of proper size of die block. Initially user has to enter part details such as sheet thickness, sheet material, etc. through user interface created using Visual Basic 6. The system stores this information automatically in a data file labeled as PART.DAT. Module also take inputs such as size of sheet from the data file SWLSEL.DAT and direction of sharp edge of the strip along width and feed length of sheet respectively from data files SEDGEW.DAT and SEDGEF.DAT generated during execution of module SWLSEL developed earlier by authors for selection of strip width and feed distance [19]. The expert advices imparted by the module DBLCK in form of thickness, width and length of die block are automatically stored in an output data file DBDIM.DAT.

3.2.2 Module DBLCKMOD

The second module labeled as DBLCKMOD is developed for automatic modeling of die block of deep drawing die. Initially user loads the module through drop down menu. The inputs to this module in form of the dimensions of die block and fasteners are read automatically from output data files generated respectively during the execution of module DBLCK and earlier developed module for selection of fasteners [18]. Module invites the user to select his choice to display 2D model or 3D model of die block. When user clicks on any one, system automatically opens AutoCAD software and generates 2D model or 3D model as per choice entered by the user. Module also calculates the location of hidden points of views of die plate. To draw orthographic views of die plate, commands such as LINE, CIRCLE, LAYER, LTYPE, etc. of AutoCAD are automatically invoked and for 3D solid modeling AutoCAD commands such as 3DORBIT, 3DEXTRUDE, UNION, SUBTRACT, etc. are invoked. Module also inserts the strip-layout from drawing file MSLYT generated during execution of earlier developed system for strip-layout [19] at an appropriate location on die plate. For development of 3D model a function in AutoLISP language is inbuilt in the module. The module is designed to save the top and front views of die plate automatically as a global block namely WDBMOD for its further use in modeling of die assembly.

3.3 Sample run of the proposed system

The proposed expert system has been tested for design of die block for various types of deep drawn sheet metal parts. A sample run of the system for one industrial sheet metal part (Fig. 2) is shown through Fig. 3 to 7. The first module DBLCK of proposed system imparts expert advices for selection of appropriate size of die block as shown in Fig. 3, 4 and 5. The second module DBLCKMOD automatically generates 2D and 3D drawing of die block in drawing editor of AutoCAD as shown in Fig. 6 and 7. The outputs of proposed system are found to be reasonable and very similar to those actually used in industry namely M/s Shreyash Tools and Components, Pune, India for the example component. Notable features of the proposed system are its parametric approach and low cost of implementation.

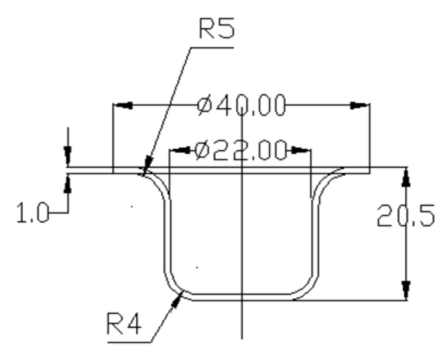

Fig. 2 Example Component (All dimensions in mm; Sheet material: M.S, Sheet thickness: 1.0 mm)

4. Conclusion

An expert system has been developed for quick and effective design of die block of deep drawing die. This system is based on KBS approach of AI. It is coded using AutoLISP language on AutoCAD platform. The proposed system has been tested by taking various types of industrial sheet metal deep drawn parts for design of die block. The proposed system allows the designer to design and model the die block quickly. Even a novice who may have little knowledge of die design can also perform the tedious task of design of die block using the proposed system easily.

Authors are engaged in the development of an integrated expert system for overall design of progressive deep drawing die.

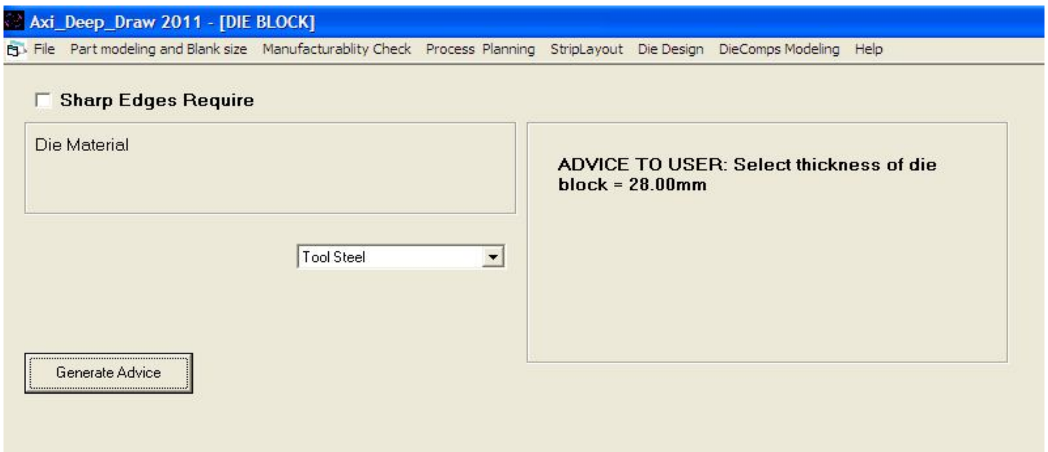

Fig. 3 System Output of DBLCK Module for Thickness of Die Block

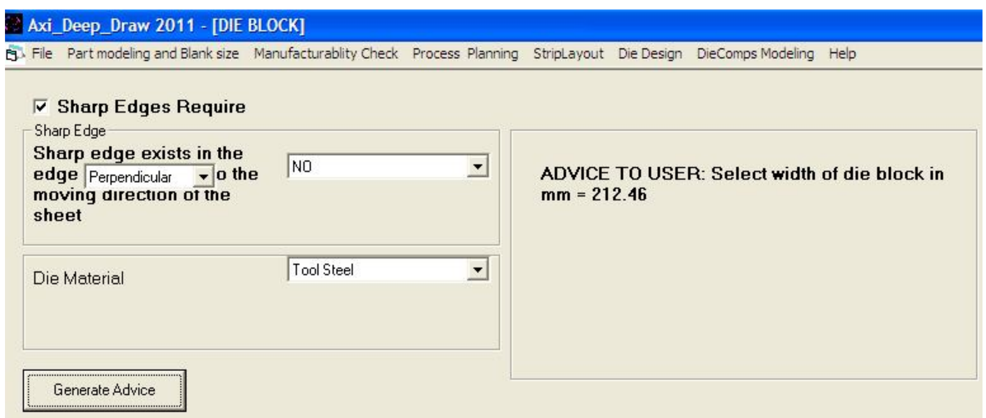

Fig. 4 System Output of DBLCK Module for Width of Die Block

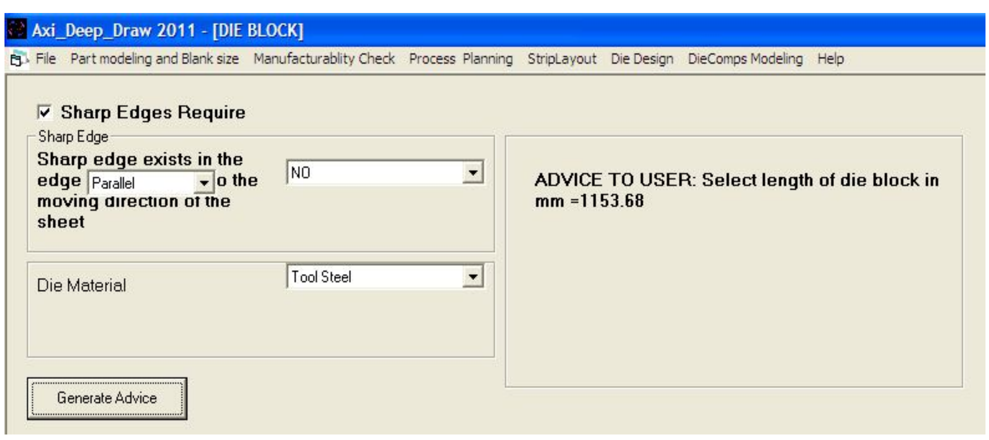

Fig. 5 System Output of DBLCK Module for Length of Die Block

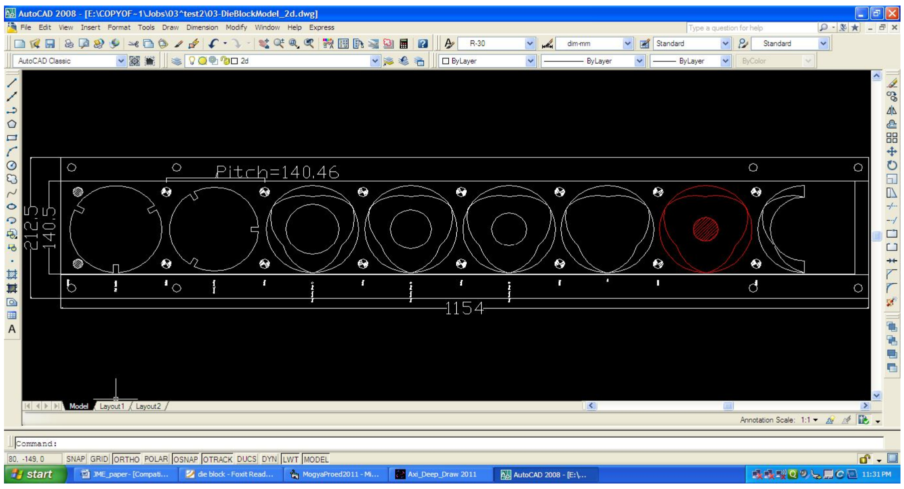

Fig. 6 System Output of DBLCKMOD Module (2D Modeling of Die Block)

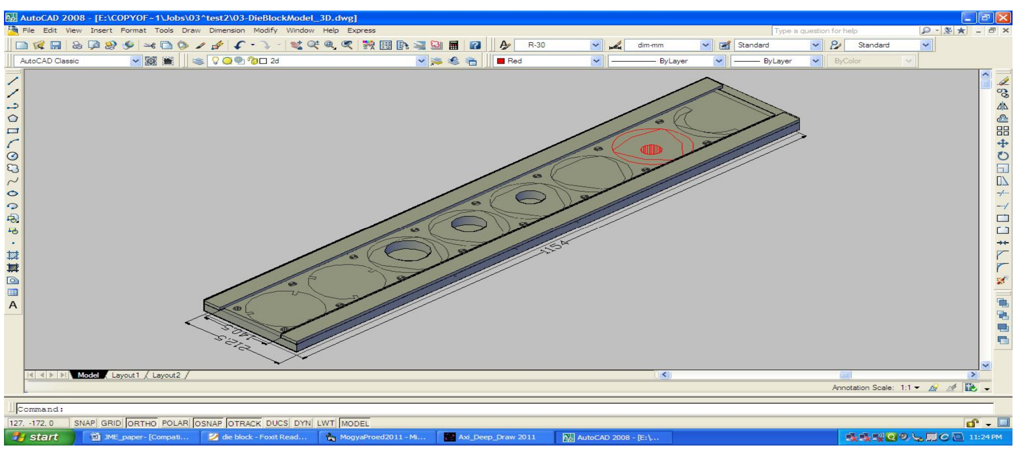

Fig. 7 System Output of DBLCKMOD Module (3D Modeling of Die Block)

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