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A knowledge-based system for selection of progressive die components

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ABSTRACT

Purpose: The present paper describes a knowledge-based system (KBS) developed for selection of progressive die components to automate the design process of progressive dies in stamping industries.
Design/methodology/approach: The production rule based KBS approach of Artificial Intelligence (AI) has been utilized for constructing the proposed system. The system has been structured into seven KBS modules. Modules are user interactive and designed to be loaded in to the prompt area of AutoCAD.
Findings: The output of system modules includes the type and proper dimensions of progressive die components namely die block, die gages (front spacer and back gage), stripper, punches, punch plate, back plate, die-set and fasteners. The system has been designed in such a way that the expert advices imparted by its modules are automatically stored in different output data files. These data files can be further utilized for automatic modeling of die components and die assembly.
Research limitations/implications: Although the system is limited to the design of progressive dies only, yet it can be extended further for the design of other types of dies also.
Practical implications: The proposed system is ready for use in sheet metal industries for quick selection of progressive die components. The system can be implemented on a PC having AutoCAD software and therefore its low cost of implementation makes it affordable by small and medium sized stamping industries.
Originality/value: The proposed system is capable of accomplishing the time-consuming task of selection of progressive die components in a very short time period.
Keywords: Automation engineering processes; Knowledge-based system; Progressive die components

1. Introduction

The design of progressive dies is a complex and highly specialized procedure [1]. The diverse nature of products produced by progressive dies demands a high level of knowledge on the part of the die designer that can only be achieved through years of practical experience [2]. Selection of type and proper dimensions of die components is a major activity for designing a progressive die. The traditional methods of carrying out this task require expertise and are largely manual and therefore tedious, time consuming and error-prone. Commercially available CAD/CAM systems are providing assistance in drafting and analysis in die design process, but human expertise is still needed to arrive at the final design. Also, the high cost associated with setting up such systems is quite often beyond the reach of small and medium sized sheet metal industries, especially in developing countries. To overcome these problems, there is an urgent need to develop an intelligent system for progressive die design to assist die designers and process planners working in sheet metal industries, especially small and medium sized stamping industries. The system should be capable of providing an intelligent aid to the die designers for automating the major activities of progressive die design process including selection of die components.

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Knowledge-based systems (KBS) or expert systems [3] are the most significant practical products to emerge from 30 years of Artificial Intelligence (AI) research. While there have been numerous applications of KBS in manufacturing, few of them concern press tools, and even fewer are for progressive dies. Progressive die design is a very knowledge demanding process. Designers often base their decisions on past experience rather than theoretical knowledge and to some extent; it remains a process of trial and error. In today's highly competitive industrial scenario where there is a shortage of experienced die designers, the requirement of high quality products with short lead times and low cost have emphasized the importance and urgency of developing computer aided progressive die design systems with embedded and easily modifiable knowledge. This is a task, which needs both existing conventional CAD technology and KBS approach [4, 5] and that is the aim of this research. Various researchers [6-8] have used AI techniques to deal with the problems, which require domain expertise for their solution. The main reason of there being only a few KBS developed for die design and even fewer for progressive dies, is the inherent difficulties to elicit the design know-how from experienced die designers and then to code the same into the knowledge base of an expert system [9]. Also the use of these systems is very limited. They can either handle only blanking and piercing operations or parts with relatively simple geometry. Thus, there is a stern need to develop a low cost intelligent progressive die design system using both CAD and KBS approach collectively, which can be easily affordable by small and medium scale sheet metal industries. The aim of present work is to develop a KBS named as PROCOMP for selection of progressive die components to automate the design process of progressive dies in stamping industries.

2. Methodology of development of the proposed system PROCOMP

The proposed system PROCOMP has been developed using production rule-based KBS approach of AI. A brief description of design considerations, development procedure and organization of the system is given as under.

2.1. Design considerations for progressive die components

The progressive die is very complex and even an ordinary die may have several components [10-12]. Major components of a progressive die are die block, die gages (front spacer and back gage), stripper plate, punch plate, back plate, punches, pilots, die-set and fasteners. Critical investigation reveals that the dimensions of die block depend on various factors such as sheet thickness, direction of sharp edge, strip-width, length of strip-layout, and type of die material. The dimensions of front spacer and back gage mainly depend on the sheet thickness. But minimum thickness of die gages is also restricted by risk of camber which may occur during heat treatment process of its manufacturing. The distance between back gage and front spacer depends on the width of stock strip. The size of stripper plate corresponds to the size of die block. The punch plate is used to position and support the punches. The thickness of punch plate is a function of punch diameter. Punch plate thickness should also be proportional to the overall punch height. The length and width of the punch plate is usually same as of die block. Hardened back-up plates are normally interposed between small perforator punches and the punch holder. The backup plate is generally about 10-12 mm thick. In the selection process of die-set of progressive die, one should consider part quantity, dimensional tolerance of the component, clearance between punch and die, and clearance between guideposts and bushings. Selection of the kind of die-set depends upon the type of sheet metal operation, part quantity and job accuracy. The dimensions of the die-set depend upon the length and width of the die and its placement in the die-set. In industries, the number and size of fasteners are selected on the basis of size of die block.

2.2. Development procedure of the system

Development procedure of the proposed system PROCOMP includes knowledge acquisition, framing of production rules, verification of production rules, sequencing of production rules, identification of suitable hardware and computer language, construction of knowledge base, choice of search strategy, and preparation of user interface. The system has been developed on PC (Pentium 4 CPU, 2.4 GHz, 256 MB of RAM) with Autodesk AutoCAD software [13]. The production rules incorporated in the proposed system have been coded in AutoLISP language [14]. The system works with input information supplied by the user coupled with knowledge stored in the knowledge base, to draw conclusions or recommendations for design of progressive die components. The system overall comprises of more than 650 production rules. However, the system is flexible enough as its knowledge base can be updated and modified, if necessary, on the advancement in technology.

2.3. Organization of the system

As the progressive die has several components, therefore it has been decided to organize the proposed system PROCOMP into the following modules -

1. Module DBLOCK for selection of dimensions of die block.
2. Module DIEGAGE for selection of dimensions of die gages (front spacer and back gage) and optimal distance between die gages.
3. Module DIALCL for selection of proper die angle, die land and cutting clearance.
4. Module STRPR for selection of stripper and stripper plate.
5. Module PCHPL for selection of punch details, punch plate and back plate.
6. Module IDSS for selection of type and dimensions of die-set.
7. Module FSTNR for selection of fasteners (bolts & dowels).

The execution of the system PROCOMP is shown in Figure 1. The modules are designed to take required input data automatically from already built output data files namely COMP.DAT, SWLSEL.DAT and OPRSEQ.DAT. The system invites the user to enter part data information such as production quantity, tolerance, sheet thickness, sheet material, shear strength of sheet etc. through prompt area of AutoCAD. The system automatically stores these part data in a part data file labeled as

COMP.DAT. The data files SWLSEL.DAT and OPRSEQ.DAT are generated automatically during the execution of KBS of strip-layout of metal stamping work on progressive die developed by the authors and described in ref. [15]. The file SWLSEL.DAT stores the optimal size of sheet metal strip and the file OPRSEQ.DAT comprises of proper sequence of required sheet metal operations. As shown in Figure 1 all the modules of system are designed to store their outputs in form of dimensions of die components in various output data files named as DBLOCK.DAT, DG.DAT, DIALCL.DAT, STRPR.DAT, PPDIM.DAT, BPDIM.DAT, DSDIM.DAT, DSSEL.DAT and FSTNR.DAT. These data files can be further utilized for automating the modeling of progressive die components and die assembly.

3. Case study

During consultation, the proposed system generates friendly prompts eliciting from the user for job related data. The system output includes expert advices on the type and dimensions of progressive die components for automating the die design process. The system has been tested for wide variety of sheet metal parts. A sample of typical prompts, user responses and expert advices rendered by the system for one industrial component (Figure 2) is given in Table 1. The recommendations of the system modules were found to be reasonable and very similar to those actually used in industries, namely M/S Anurina Tristar Pvt. Ltd., New Delhi, India for example component. The system has been implemented on a PC having AutoCAD software.

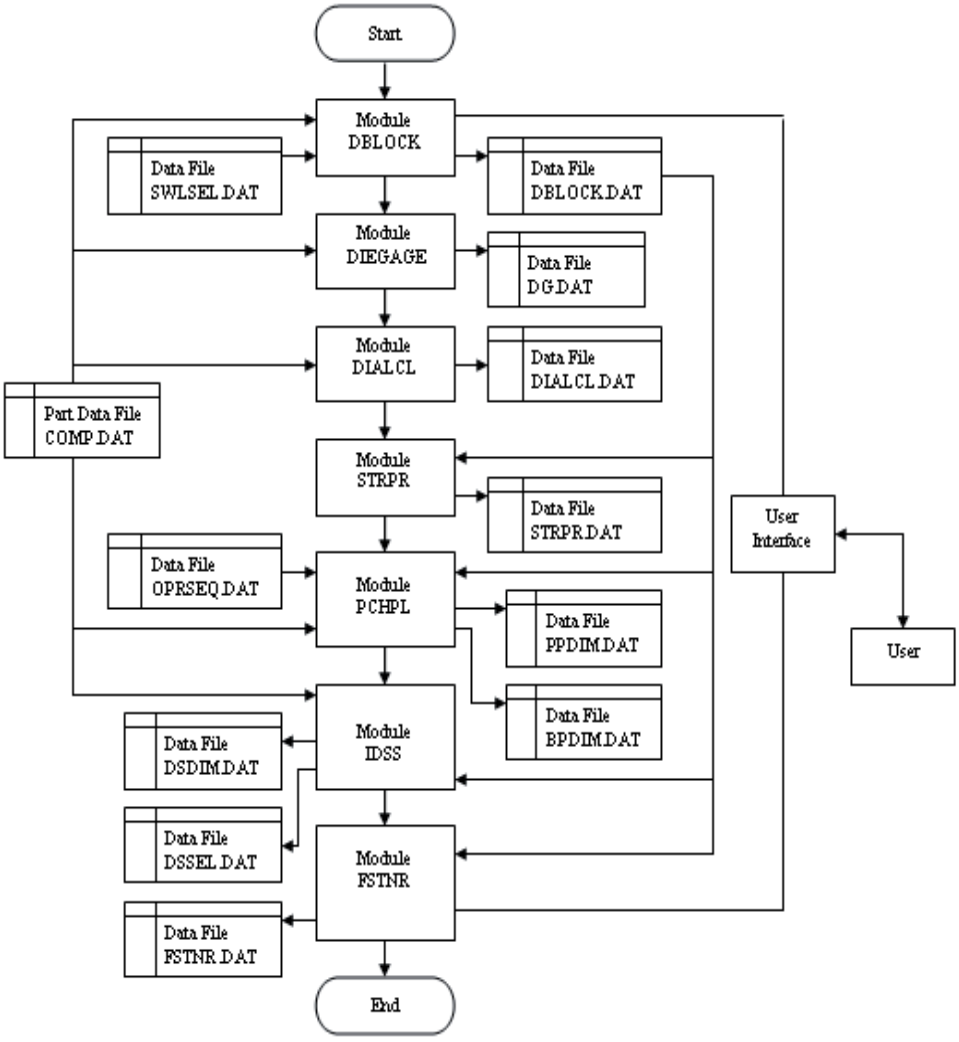

Fig. 1. Execution of the System PROCOMP

Table 1.
A sample of typical prompts, user responses and expert advices generated by the system PROCOMP for example component (Figure 2)

S. No.	Prompts	Example data entry	Advice to the user
1	(Load "A:/PROCOMP")		Welcome to the knowledge base system PROCOMP developed for selection of progressive die components.
2	Enter type of die material	Tool Steel	Select size of die block - Die block thickness in mm = 28, Die block width in mm = 160, Die block length in mm = 300. Please enter command DIEGAGE
3	Enter the shape of die hole contour	smooth	Select width of front spacer in mm =47.7, and Thickness of front spacer in mm =8.0.
4	Enter sheet material hardness (HRC)	20	Set cutting clearance all around punch and die in mm = 0.035. Please enter command STRPR
5	STRPR		Select die-size fixed-stripper of HRC 48-52 with strip width variation allowance = 2.5 mm, and channel Height in mm = (2.0 times sheet thickness)+ 0.75. Please enter command PCHPL

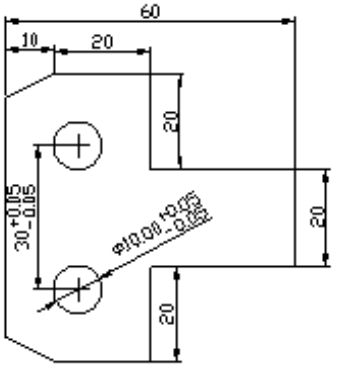

Fig. 2. Example Component 1 (All dimensions are in mm, sheet material – Brass, sheet thickness – 1.0 mm)

4. Conclusions

The present investigation contributes towards automating the design process of progressive die using KBS approach. The output of system modules includes the type and dimensions of major components of progressive die such as die block, die gages, stripper, stripper plate, punches, punch plate, back plate, die-set and fasteners. The system is flexible enough as its knowledge base can be modified and updated depending upon the capabilities of a specific shop floor and advances in new technology. The system has been tested for a wide variety of industrial sheet metal components. Recommendations imparted by the system for selection of progressive die components were found to be reasonable and very similar to those actually used in sheet metal industries. The data stored in output files generated by the system modules can be further utilized for automatic modeling of progressive die components and die assembly. The system is a low cost alternative for die designers working in small and medium sized stamping industries.

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