# An Expert System for Design of Blanking Dies for Sheet Metal Operations

S. Kumar, R. Singh, and G.S. Sekhon

*Abstract* - **This paper describes an expert system developed for assisting die designers for design of blanking dies for sheet metal operations. The production rule-based expert system approach is utilized for development of the system. The proposed system labelled as INTBDIE is organized in form of twelve modules. Modules are coded in AutoLISP language and designed to be loaded into the prompt area of AutoCAD. For consultation, the user loads the system into the prompt area of AutoCAD. The proposed system generates friendly prompt eliciting from the user for data pertaining to the job. The recommendations imparted by the system for design of blanking die are automatically stored in various output data files which are further utilized for automatic modelling of die components and die assembly. This arrangement facilitates interfacing of design with drafting and can be operated on a PC/AT. The knowledge base of the proposed system can be modified depending upon the capabilities of a specific shop floor. As the system can be implemented on a PC having AutoCAD software, therefore its low cost of implementation makes it affordable for small and medium-sized stamping industries.**

*Index Terms*—**Blanking die, Expert system, Sheet metal operations, Stamping industries.**

## I. INTRODUCTION

The process of design and modelling of blanking die for sheet metal operations is quite systematic and involves various activities such as checking of part design features from manufacturability point of view, choice of manufacturing operations, selection of the type of die, selection of the press machine and selection of the dimensions of the die components. This process remains even today highly complex and time-consuming [1]. This is on account of the fact that the die designer is called upon to effect trade-offs between a numbers of mutually conflicting factors at initial stages of design. Indeed many practitioners in industry believe that the art of die design can be mastered only through long years of experience. Traditional methods of design of blanking die for sheet metal operations involve numerous calculations and decisions which have to be made on the basis of experience and practice codes without the computer aids [2]. A die designer may have to spend many hours consulting hand books, going through empirical formulae, perusing tabulated and graphical information, and making calculations before arriving at workable designs. These activities are tedious and time consuming, and often do not yield optimum results. In recent years the computer aided procedures [1], [3]-[9] are being increasingly utilized to ameliorate the above difficulties. But there is not a single system which is capable to accomplish the complete design process of blanking die. Commercially available CAD/CAM systems are providing some assistance in drafting and analysis in die design process, but human expertise is still needed to arrive at the final design [10]. 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. There exists therefore, the need of developing an expert system for design of the blanking die. The system should be capable of providing expert advices to the planners of sheet metal operations especially one employed in the small scale stamping industries.

The specific objective of the present work is the development of an expert system for assisting the die designer for designing and modelling of blanking die. The production rule-based expert system approach is utilized for development of the proposed system. The remaining of this paper is organized as follows: Section 2 presents the procedure for development of the system. Section 3 gives the description of the proposed expert system. Section 4 demonstrates the usefulness of the proposed system using an industrial component. The last section gives conclusion of this paper.

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## II. PROCEDURE FOR DEVELOPMENT OF THE PROPOSED SYSTEM

The proposed system for design of blanking die for sheet metal operations comprises of twelve modules. A brief description of procedural steps [11] used for development of each module is given as under.

### A. Collection of information for design of blanking die

Information for design of blanking die were collected from a variety of sources including die design handbooks, industrial brochures, monographs, research journals, experienced die designers and shop floor engineers. The process of knowledge acquisition from experienced die designers involves presenting a few typical problems of blanking to the expert(s) and letting the expert(s) talk through the solution. During the verbal analysis, the expert(s) may be questioned / interrupted to explain why a particular decision was reached. Knowledge may be acquired from domain experts by holding discussions on typical problems pertaining to the die design and letting the experts talk about the approach, formulae and thumb-rules relied upon by them. They may be asked as to how and why a particular decision can be reached. This is to identify the parameters influencing particular decision.

### B. Framing of production rules for each module of the proposed system

The production rule-based system is the earlier and more popular approach to represent analytical, heuristic or experience-based knowledge. Heuristic knowledge acquired for each module of the system INBDIE was framed into the production rules of IF (action) - THEN (conclusion) variety.

### C. Verification of production rules

The production rules framed for an expert system must be verified from a team of domain experts by presenting them IF-condition of the production rules and then matching their recommendations with the THEN-action part of rules. The production rules framed for the proposed system were properly verified from a team of experienced die designers.

### D. Encoding of production rules for each module of proposed system

LISP and PROLOG are widely used for constructing expert systems. But the user of these languages encounters difficulties when handling design problems involving graphical information. For this reason AutoCAD and AutoLISP have found greater acceptance in design and manufacturing, evaluation of design alternatives, and creation of drawings. Expert system applications involving graphical data can be built by combining AutoLISP and AutoCAD [12]. For this reason, the present system makes use of AutoLISP and AutoCAD facilities for encoding the production rules of each module.

### E. Preparation of user interface

The purpose of user interface is two fold. It enables the user to input the essential job related data to each module and it displays the optimal design choices for the user's benefit. This is achieved by making the interface flash prompts at appropriate stages during a consultation inviting the user to input data items. It also displays messages or advice on the computer screen at appropriate times. The user is also guided in a friendly manner throughout the consultation on how to proceed further at each different stage. The user initially loads the proposed expert system by using the command (Load "A: INTBDIE.LSP") in prompt area of AutoCAD. The program, after compilation, is ready for serving the user.

## III. DESCRIPTION OF THE PROPOSED EXPERT SYSTEM

The proposed system INTBDIE is organized into twelve modules namely PARTDGN, PROPLAN, TLDGN, PRESS, DIE, DILACL, CLAA1, STRIPPER, PUNCH, DSSEL, DISETDIM, and FASTNER. A brief description of each module is given as under.

### A. Module PARTDGN

The first module labelled as PARTDGN is developed for assisting the user for carrying out the design check on sheet metal parts. The module incorporates an interface for displaying friendly prompts to guide the user during a consultation session. The input data supplied by the user is also stored in a file, called as PART.DAT for use in subsequent modules.

### B. Module PROPLAN

The module PROPLAN is developed for selection of sheet metal operations. The decision of selection of suitable operations for manufacturing a specified sheet metal component depends on a number of factors such as part design, sheet material, production quantity, quality specifications, installed facilities, and available dies and tools etc. The module PROPLAN is designed to call the data file PART.DAT. During a consultation session, the user is also invited by the module to feed inputs necessary for making the selection of the manufacturing operations for a given component. The data related to the kind of sheet operation, generated during execution is appended in the file PART.DAT for further use in subsequent modules.

### C. Module TLDGN

This module is designed for assisting the user in the selection of suitable type of die for a given job. Altogether 55 production rules were framed for this module.

### D. Module PRESS

The module PRESS is framed for optimal selection of the press machine. This module initially computes and displays the minimum force required for carrying the needed sheet metal operation for the benefit of the user and identifies the alternative machines which can be used for the job. Afterwards the user is invited to supply data regarding fixed and operating costs for each candidate press machine in turn. The production cost per unit is computed and retained in memory for as many candidate machines as required. In the end, the module identifies the press for which the cost per unit is likely to be the smallest.

### *E. Module DIE*

This module is developed to assist the user to select correct size of the die block. Parameters affecting the size of die block include sheet thickness, total blank perimeter, contour width, contour length and direction of the sharp edge of strip and the die material. The width of strip is stored in file SSLW.DAT. The module DIE has more than 40 production rules coded in AutoLISP. The recommended size of die block is automatically stored in a file labelled as DIE.DAT which is further used for modelling of die components and die assembly.

### *F. Modules DILACL AND CLAA1*

The Modules DILACL and CLAA1 are developed for selection of die-land, die-angle and cutting clearances. The cutting clearance per side depends upon the thickness, shearing strength and hardness of the sheet material, job accuracy and the type of operation. The recommendations imparted by these modules are automatically stored in a file labelled as CLAA.DAT which may be recalled during the execution of subsequent modules.

### *G. Module STRIPPER*

This module is constructed for assisting the user in the selection of stripper details. Type and size of stripper depends upon component thickness, job accuracy and the kind of operation. The dimensional data recommended by the module STRIPPER is stored automatically in a data file named as STRIPPER.DAT for its further use in the automatic modelling of stripper plate.

### *H. Module PUNCH*

The module PUNCH is developed for selection of the type and size of punches. It also assists in the selection of proper size of punch plate and back up plate. The expert advices imparted by this module are automatically stored in an output data file labelled as PUNCH.DAT for its further use in the automatic modelling of punch, punch plate and back up plate.

### *I. Modules DSSEL and DISETDIM*

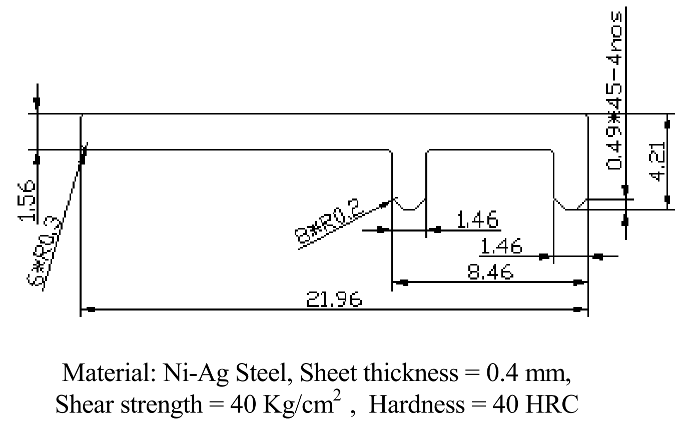
The modules DSSEL and DISETDIM are framed for assisting the user for selection of type of die-set and its size. Selection of the type of die-set depends upon the type of sheet metal operation, part quantity and job accuracy. The size of the die-set depends upon the size of the die and its placement in the die-set. For automating the design process, the type of die-set as recommended by the module DSSEL is automatically stored in a file labelled as DSSEL.DAT. The dimensional data namely size of bottom and top bolster of die-set, diameters of guide pillars and guide bushes as recommended by the another module DIESETDIM are automatically stored in a file labelled as DISETDIM.DAT for its further use in modelling of die components and die assembly.

### *J. Module FASTNER*

The module FASTNER is developed for selection of number and size of fasteners (bolts and dowels). The module automatically stores the recommended diameter of fasteners in a file named as FASTNER.DAT for its further use in modelling of die components and die assembly.

## IV. ILLUSTRATIVE EXAMPLE

The proposed system INTBDIE has been tested for wide variety of sheet metal parts for design of blanking die. A sample of typical prompts, user responses and advices generated by the system for one example component (Fig. 1) are depicted through Table 1. The different modules of the proposed system render enough advices and provide sufficient design data for modelling of blanking die. The system also generates drawings of die components and die assembly automatically in the drawing editor of AutoCAD. Orthographic views of the lower portion of assembled blanking die automatically generated by the proposed system are shown in Fig. 2. The recommendations obtained by the proposed system and drawings generated by the system for example component were found to be reasonably close to those actually used in industry namely M/S Indian Telephone Industries, Rae-Barely, India for the example component.




Material: Ni-Ag Steel, Sheet thickness = 0.4 mm,
Shear strength = 40 Kg/cm$^2$ , Hardness = 40 HRC

Fig. 1 Example component (All dimensions are in mm)

Table 1. Typical prompts, user responses and expert advices imparted by the system for example component

| S. No. | Typical Prompts | User Responses | System Advices |
|---|---|---|---|
| 1 | (LOAD “A: INTBDIE.LSP”) | | Please enter command PARTDGN |
| 2 | PARTDGN | | Welcome to the module PARTDGN developed for checking part design features. |
| | Enter production quantity | 120000 | |
| | Enter required tolerance (mm) | 0.01 | |
| | Enter sheet thickness (mm) | 0.4 | |
| | Enter shear strength ($Kgf/mm^2$) | 40.0 | |
| | Enter corner radius of part (mm) | 0.3 | Accept the corner radius. Please enter command PROPLAN |
| 3 | PROPLAN | | Welcome to the module PROPLAN developed for identification of sheet metal operations |
| | Enter kind of feature on product | external precision contour | Required operation = blanking.<br>Please enter command TLDGN |
| 4 | TLDGN | | Welcome to the module TLDGN developed for selection of type of die. |
| | | | Design blanking die. Please enter command PRESS |
| 5 | PRESS | | Welcome to the module PRESS. Calculate perimeter of the blank using command AREA of AutoCAD |
| | Enter blank perimeter in mm | 58.0 | |
| | Enter production rate per minute | 10 | Computed press tonnage (ton.) = 0.944. Select hand, mechanical, hydraulic or pneumatic press of 5 or 10 tons capacity. Please enter command DIE. |
| 6 | DIE | | Welcome to the module DIE developed for selection of size of the die. |
| | Enter die material | Tool steel | |
| | Enter strip-layout width (mm) | 25.0 | |
| | Enter type of sheet material | Ni-Ag steel | |
| | Enter sheet metal hardness (HRC) | 20.0 | |
| | Enter component width (mm) | 4.21 | Set die thickness (mm) = 16.0, die width (mm) = 100.0, die length (mm) = 80.0, and Set positive tolerance on internal contours of slots of die (mm) = 0.004. Please enter command DILACL |
| 7 | DILACL | | Welcome to the module DILACL developed for selection of die-land, die-angle and clearance on punch and die<br>Set die-land (mm)= 3.0, die-angle (deg.) = 0.4, and Set Clearance on punch and die (mm) = 0.02. Please enter command STRIPPER |
| 8 | STRIPPER | | Welcome to the module STRIPPER developed for selection of details of the stripper. Use die size fixed stripper with HRC 45-50, strip width variation allowance = 2.0 mm and Channel width = 150% of strip thickness + 0.75 mm. Please enter command PUNCH |
| 9 | PUNCH | | Welcome to the module PUNCH developed for selection of details of the punch |
| | | | Set Minus tolerance (mm) on external punching contours = 0.004.<br>Please enter command DIESET |

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| | | | |
|---|---|---|---|
| 10 | DIESET | | Welcome to the module DIESET developed for selection of the kind of die-set and its dimensions.<br>Use die-set of 2 flat bushings on top bolster and 2 guide posts on bottom bolster, and Place die perpendicular in rear pillar (diameter 19 mm) die set having length, width and thickness of bottom bolster (mm) as 150, 145 and 39. Please enter command FASTNER. |
| 11 | FASTNER | | Use 4 Allen bolts M 8 and 2 dowels of diameter = 10 mm |

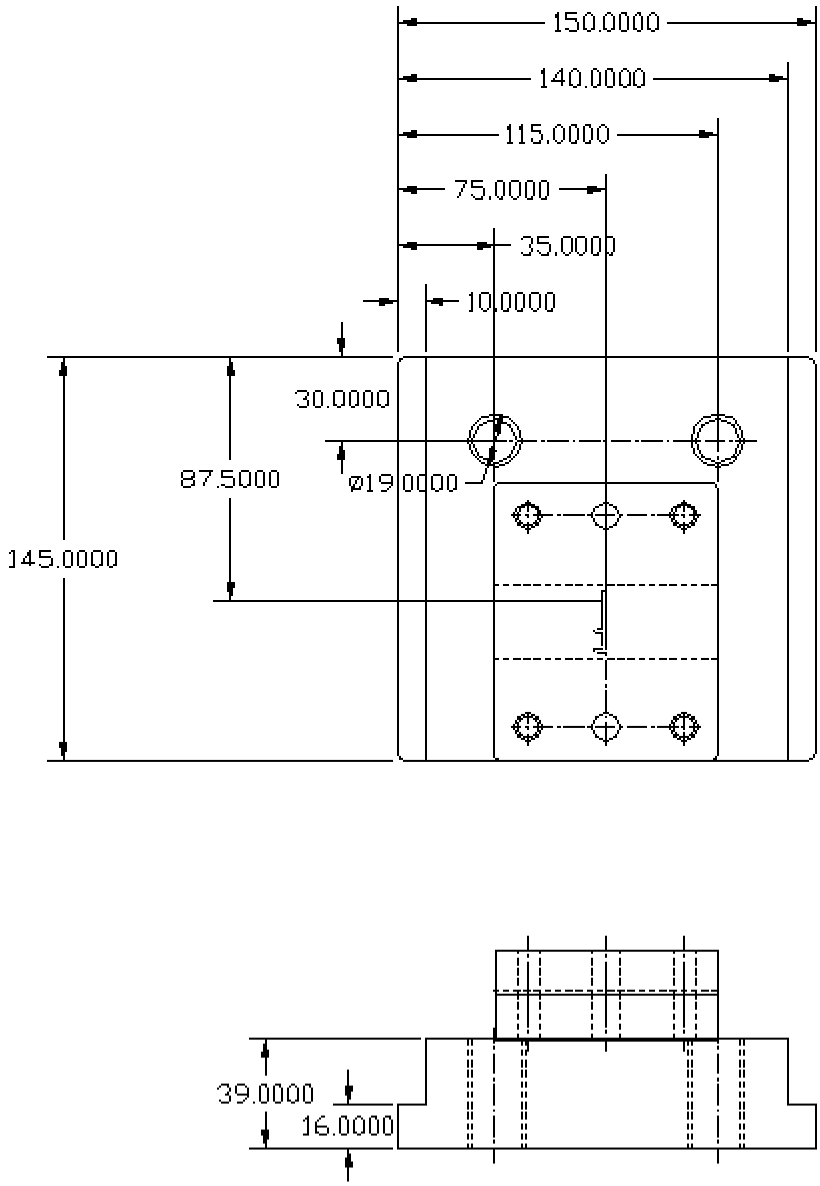


Fig.2 Orthographic views of lower portion of assembled blanking die generated automatically by the proposed system

## V. CONCLUSION

The proposed system has been developed using production rule-based expert system approach of artificial intelligence. Knowledge for the design of blanking die obtained from die designers, hand books, catalogues and brochures has been analysed, tabulated and incorporated into production rules of IF-THEN variety. These rules were coded in AutoLISP language. The system has been organized into twelve modules. Modules are user interactive and designed to be loaded in to the prompt area of AutoCAD. System modules are capable to impart expert advices on checking manufacturability of part, selection of press machine and selection of die components. Expert advices imparted by the system modules are automatically stored in various output data files, which are utilized for automatic modelling of blanking die. The system has been tested for a wide variety of industrial sheet metal parts. Recommendations imparted and drawings generated by the system were found to be reasonable and very similar to those actually used in sheet metal industries. The system is capable of accomplishing the tedious and time-consuming task of blanking die design in a very short time period. As the system can be implemented on a PC having AutoCAD software, therefore it is a low cost alternative for process planners and die designers working in small and medium sized stamping industries.

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