Journal of Manufacturing Engineering, March, 2014, Vol. 9, Issue. 1, pp 016-021

CDPUN: AN EXPERT SYSTEM FOR SELECTION OF COMPOUND DIE PUNCHES

[*]Sachin Kashid[1] and Kumar S [2]

[1]Research Scholar, Department of Mechanical Engineering, S.V. National Institute of Technology, Surat, Gujarat-395007
[2]Associate Professor, Department of Mechanical Engineering, S.V. National Institute of Technology, Surat, Gujarat- 395007

ABSTRACT

Selection of punches is an important activity for the design of a compound die. This paper describes an expert system labeled as CDPUN developed for selection of punches of compound die. For the development of proposed system technical knowledge is acquired from various sources of knowledge acquisition and represented by using production rules of 'IF-THEN' variety. Rules are coded in AutoLISP language and graphical user interface is created using Visual Basic (VB). The system is capable of imparting expert advices for sequence of punches (upper punch and lower punch), selection of type and size of punches, and punch plate. Further, system also imparts expert advices for determination of clearance between punch and die block. The proposed system can be implemented on a PC having VB and AutoCAD softwares, therefore its low cost of implementation makes it affordable even for small scale stamping industries.

Keywords: *Expert System, Punches, Compound Die, Production Rules, AutoCAD and Stamping Industries*

1. Introduction

Selection of punches is an important activity in the design of a compound die. Selection of punches mainly depends upon the area to be blanked or pierced. A piercing punch of compound die is shown in Fig.1. Punches of compound die are classified as plain punch, pedestal punch and perforated punch. For the design of a compound die, die designer has to select proper type of punches, determine size of punches and punch plate, and proper clearance between punch and die block. Traditionally, these activities are carried out manually in sheet metal industries by experienced die designers. Manual selection of punches of compound die is tedious, time consuming, labour intensive and error prone [1]. Therefore, most of die designers working in sheet metal industries still believe that it is an art rather than science.

Fig. 1 Piercing Punch

Some researchers applied efforts to develop expert systems for die design including selection of punches. For example, Nakahara et al. [2] developed a CAD/CAM system for automation of design of progressive die. The concept of basic patterns is used corresponding to the standard punches for creating blank and tool configurations. However, the capability of the system has not been tested to tackle real life problems. Adachi et al. [3] proposed an integrated CAD system for progressive dies. This system needs the assistance of experienced designer for design and selection of guiding and fastening elements. Nee and Foong [4] reviewed the techniques employed in design of progressive die punches and made an attempt to link the programs together to form a useful package for the design of progressive dies for bending and forming operations. Nee [5] proposed a CAD system for automation of progressive die design. The limitations of this system are its approximate calculation of blank and bend allowance; and intervention of expert designer to generate the assembly views interactively. Sing and Rao [6] developed an expert system for process planning of axisymmetric deep drawing parts. In this system the knowledge base is represented by production rules and frames. Outputs of the system are in the form of blank development, blank layout design, number of draws, and calculation of clearance, air vent hole, tool radii, punch force and blank holding force. Lin and Hsu

*Corresponding Author - E- mail: skbudhwar@med.svnit.ac.in

[7] proposed an automated design system for drawing dies. It uses pre-built design knowledge base and database to design the main components of a drawing die. Hwang et al. [8] reported to develop an automated progressive design system with multiple processes such as piercing, bending and deep drawing for manufacturing products. Kumar and Singh [9] developed an automated system for design of progressive dies. Naranje and Kumar [10] proposed a KBS for selection of components of deep drawing die. Production rules are coded in Auto LISP language and user interface is created in Visual Basic 6.0 on AutoCAD platform. The proposed system deals with only deep drawing die. Potocnik et al. [11, 12] developed a KBS for supporting the design of a press plate. The system deals with CATIA software, therefore it requires experienced person to operate.

From the review of available literature it is found that the applications of expert system are explored mainly for design of single operation dies, progressive die, deep drawing die and bending die. These systems are capable to select type and size of punches also for sheet metal operations. But no system is reported in the literature developed for selection punches of compound die. It is well known that scarcity of experienced die designers has caused much inconvenience to the sheet metal industries. Therefore, there is a stern need to develop an expert system for selection of punches of compound die. In the present work, research efforts are applied to develop and expert system to automate this task.

2. General Considerations for Selection of Punches

From the critical review of published literature [13-16] and detailed discussion with experienced die designers [17], some basic guidelines for selection of punches of compound die are identified. A sample of these basic guidelines is given as under.

i. The flange of pedestal punch should be wide and thick enough to provide space for holes.
ii. Diameter of piercing punches should not be smaller than the sheet thickness.
iii. The punches over 100 mm unguided length should be avoided. Otherwise, a spacer block should be used in between punch and punch plate.
iv. Enough clearance must be provided around the punch for its easy removal.
v. The length of punch is usually taken as 8.0 times of its diameter.
vi. Sufficient number of screws should be used on punch plate to overcome stripping load.
vii. Minimum distance from punch plate edges to screw centers is recommended as 1.5 times of screw diameter.
viii. Small notching punches are usually held in their punch plate by means of slots machined in the top surface of plate.
ix. When high blanking and piercing pressures are required, it is necessary to increase length of punch.
x. If piercing and blanking operation are to be performed on sheet metal part, then upper punch is taken as piercing and lower punch as blanking punch.
xi. If notching and blanking operation are to be performed on sheet metal part, then upper punch is taken as notching punch and lower punch as blanking punch.
xii. If parting and shaving operation are to be performed on sheet metal part, then upper punch is taken as shaving punch and lower punch as parting punch.
xiii. Generally long socket cap screws are used on top of die-set.

Keeping in view of the above basic guidelines and detailed discussions with experienced die designers, an expert system labeled as CDPUN is developed for selection of punches of compound die.

3. Proposed Expert System ‘CDPUN’

The procedure for development of proposed system 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. Knowledge for the development of proposed system is acquired through on-line and off line discussion with experienced die designers of different sheet metal industries, referring die design handbooks, technical reports, industrial brochures, research papers and manuals of various sheet metal industries. The acquired knowledge is refined and then framed in form of production rules of ‘IF-Then’ verity. The system overall consist of more than 300 production rules. The production rules framed were verified from other team of die design experts. The rules are coded in Auto LISP language. A sample of production rules incorporated in the proposed system is given in Table 1. Graphical user interface (GUI) of the proposed system is constructed using Visual Basic (VB) and interfaced with AutoCAD software and AutoLISP language. A feature library is constructed for the development of proposed system. On loading the module through GUI, drawing editor of AutoCAD displays feature library.

Table 1: A Sample of Production Rules Incorporated in the Proposed System

S No.	IF (Condition)	THEN (Action)
1.	Inner shape of part feature is circular; and Diameter of inner part feature in mm ≤ 25; and Sheet thickness in mm ≤ 0.5	Select circular plain punch; and Diameter of circular punch in mm = (inner circular hole diameter + 0.05); and Select length of punch in mm = (inner circular hole diameter in mm + 40); and Select upper and lower punch plate thickness in mm = 14.0
2.	Inner shape of part feature is circular; and Diameter of inner part feature in mm ≤ 25; and Sheet thickness in mm > 0.5; and Sheet thickness in mm ≤ 0.8	Select circular plain punch; and Diameter of circular punch in mm = (inner circular hole diameter + 0.06); and Select length of punch in mm = (inner circular hole diameter in mm + 45) ; and Select upper and lower punch plate thickness in mm = 14.0
3.	Inner shape of part feature is circular; and Diameter of inner part feature in mm > 25; and Diameter of inner part feature in mm ≤ 35; and Sheet thickness in mm > 0.5; and Sheet thickness in mm ≤ 0.8	Select circular plain punch; and Diameter of circular punch in mm = (inner circular hole diameter + 0.06); and Select length of punch in mm = (inner circular hole diameter in mm + 50) ; and Select upper and lower punch plate thickness in mm = 14.0
4.	Inner shape of part feature is square; and Dimension of inner part feature in mm >35; and Dimension of inner part feature in mm ≤ 70; and Sheet thickness in mm > 0.8; and Sheet thickness in mm ≤ 1.2	Select square plain punch; and Dimension of square punch in mm = (inner square hole dimension + 0.1); and Select length of punch in mm = (inner circular hole diameter in mm + 90) ; and Select upper and lower punch plate thickness in mm = 16.0
5.	Inner shape of part feature is rectangular; and Dimension of inner part feature in mm >70; and Dimension of inner part feature in mm ≤ 100; and Sheet thickness in mm > 2.5; and Sheet thickness in mm ≤ 3.5	Select pedestal punch; and Dimension of pedestal punch in mm = (inner rectangular hole dimension + 0.3); and Select length of punch in mm = (inner circular hole diameter in mm + 150) ; and Select upper and lower punch plate thickness in mm = 18.0
6.	Outer shape of part feature is oblong; and Dimension of outer part feature in mm > 35; and Dimension of outer part feature in mm ≤ 70; and Sheet thickness in mm > 0.5; and Sheet thickness in mm ≤ 0.8	Select oblong plain punch; and Dimension of oblong plain punch in mm = (outer oblong hole dimension - 0.06); and Select length of punch in mm = (outer oblong hole diameter in mm + 90) ; and Select upper and lower punch plate thickness in mm = 14.0
7.	Outer shape of part feature is rectangular; and Dimension of outer part feature in mm >100; and Dimension of outer part feature in mm ≤ 150; and Sheet thickness in mm >3.5; and Sheet thickness in mm ≤ 4.5	Select pedestal punch; and Dimension of pedestal punch in mm = (outer rectangular hole dimension - 0.4); and Select length of punch in mm = (outer circular hole diameter in mm + 210) ; and Select upper and lower punch plate thickness in mm = 20.0
8.	Outer shape of part feature is circular; and Diameter of outer part feature in mm ≤ 25; and Sheet thickness in mm ≤ 0.5	Select circular plain punch; and Diameter of circular punch in mm = (outer circular hole diameter - 0.05); and Select length of punch in mm = (outer circular hole diameter in mm + 45) ; and Select upper and lower punch plate thickness in mm = 14.0
9.	Outer shape of part feature is circular; and Diameter of outer part feature in mm > 25; and Diameter of outer part feature in mm ≤ 35; and Sheet thickness in mm >0.5; and Sheet thickness in mm ≤ 0.8	Select circular plain punch; and Diameter of circular punch in mm = (outer circular hole diameter - 0.06); and Select length of punch in mm = (outer circular hole diameter in mm + 55) ; and Select upper and lower punch plate thickness in mm = 14.0
10.	Outer shape of part feature is square; and Dimension of outer part feature in mm > 35; and Dimension of inner part feature in mm ≤ 45; and Sheet thickness in mm > 0.8; and Sheet thickness in mm ≤1.2	Select square plain punch; and Dimension of square punch in mm = (outer square hole dimension - 0.1); and Select length of punch in mm = (outer square hole dimension in mm + 65) ; and Select upper and lower punch plate thickness in mm = 16.0
11.	Required operation = piercing and blanking	Upper punch = piercing; and lower punch = blanking
12.	Required operation = notching and blanking	Upper punch = notching; and lower punch = blanking
13.	Required operation = piercing and notching	Upper punch = piercing; and lower punch = notching

Execution of proposed system is shown in Fig.3. The system works in conjunction with an expert system already developed by authors for automation of process planning of sheet metal parts produced on compound die [18]. First, the system invites the user to enter part data information such as sheet thickness, sheet material through GUI. The system stores these part data automatically in a data file labeled as PD.DAT. The module is designed to take required inputs in form of blank modeling and operation sequence respectively from data files BLKMOD.DAT and OPRSQ.DAT generated during execution of system developed for process planning [18]. As soon as the user supplied sufficient data during a consultation, the program scans through the production rules one after the other. Whenever the IF condition in a production rule gets satisfied, the system displays the THEN advice for the user. Finally, the system imparts expert advices for sequence of punches (upper punch and lower punch), type of punches, size of punches and punch plate, and clearance between punch and die block. The system automatically stores its advices in a data file labeled as CDPUN.DAT.

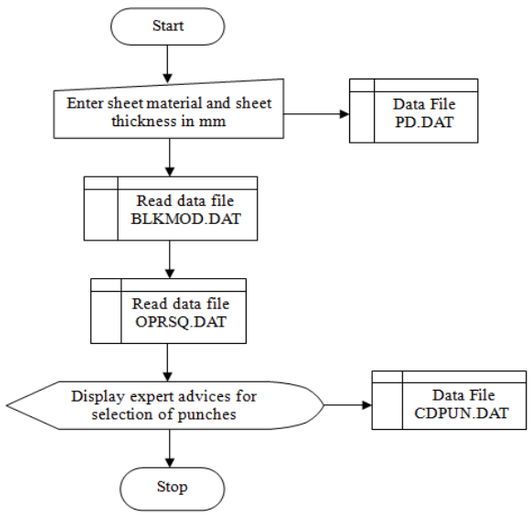

Fig. 3 Execution of Proposed System

4. Sample Runs of the Proposed System

The proposed expert system CDPUN has been validated on various types of sheet metal parts produced on compound die. Three sample runs of the system on industrial sheet metal parts as shown in Fig. 4, 5 and 6 taken respectively from stamping industries/tool rooms namely M/s D. D. Engineering Pvt. Ltd., Pune, M/s Indo German Tool Room, Ahmadabad, and M/s Panchmahal Dies and Tools Pvt. Ltd., Vadodara are depicted through screen shots in Figs. 7, 8 (for example part 1), Figs. 9, 10 (for example part 2) and Figs. 11, 12 (for example part 3).

The recommendations given by the proposed system were found to be reasonable and very similar to those actually used in these stamping industries/tool rooms for the example parts. The proposed system renders enough advices and provides sufficient design data for selection of punches of compound die. The proposed system has low cost of implementation because it can be implemented on a PC having AutoCAD software. Further, the system is flexible enough to accommodate new knowledge and/or editing of existing knowledge easily due to advancement in sheet metal technology in future.

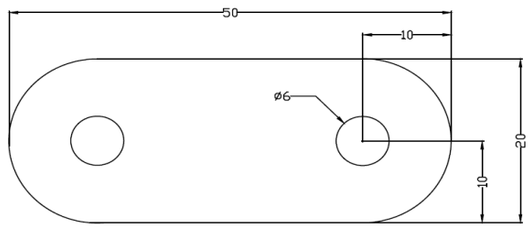

Fig. 4 Example Part 1 (All dimensions are in mm, Sheet Material = Brass, Sheet thickness = 0.6mm)

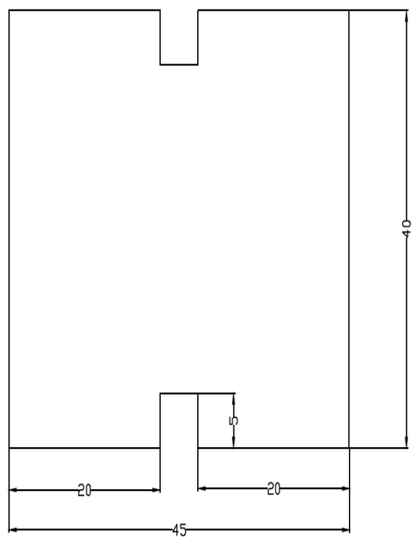

Fig. 5 Example Part 2 (All dimensions are in mm, Sheet Material = Copper, Sheet thickness = 0.5mm)

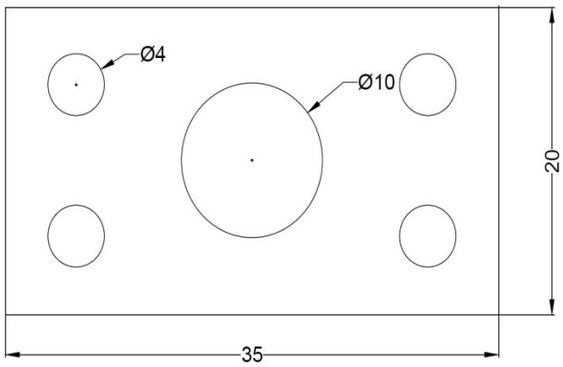

Fig. 6 Example Part 3 (All dimensions are in mm, Sheet material = Stainless Steel, Sheet thickness = 0.8mm)

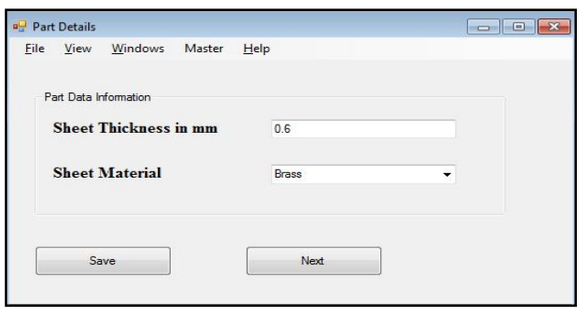

Fig. 7 Inputs to the Proposed System for Example part 1

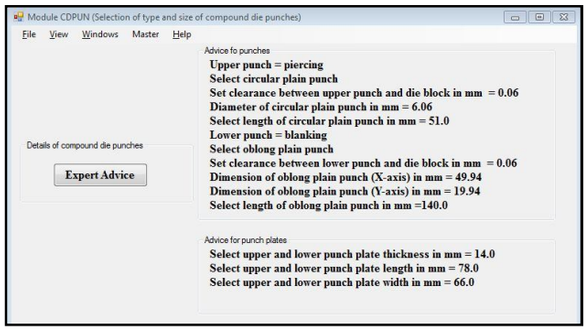

Fig. 8 Output of the Proposed System for Example Part 1

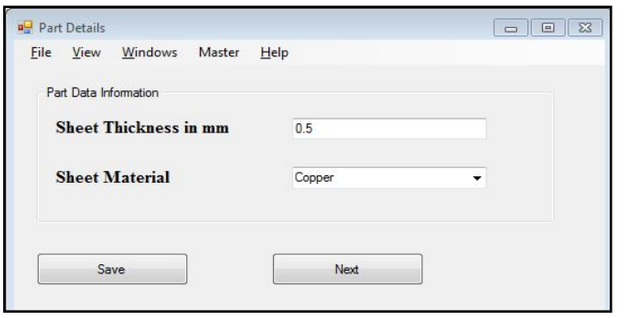

Fig. 9 Inputs to the Proposed System for Example Part 2

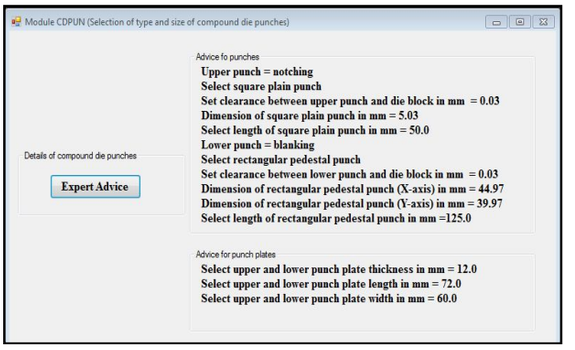

Fig. 10 Output of the Proposed System for Example Part 2

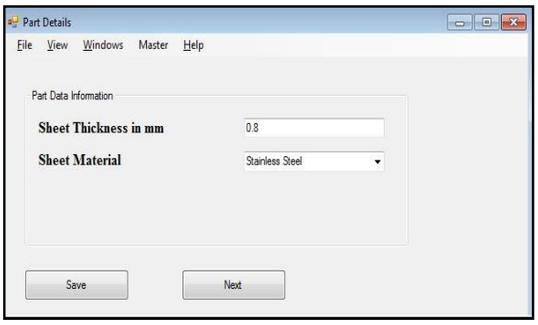

Fig. 11 Inputs to the Proposed System for Example Part 3

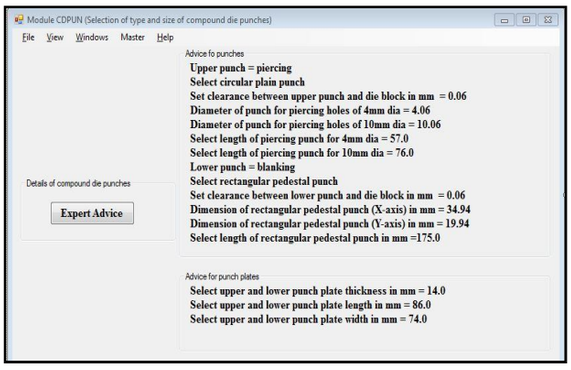

Fig. 12 Output of the Proposed System for Example Part 3

5. Conclusion

In this paper, research work involved in the development of an expert system for selection of punches of compound die is described. The proposed system is capable to impart expert advices for sequencing of punches (upper punch and lower punch), type of punches, size of punches and punch plate, and clearance between punch and die block. Usefulness of the system is demonstrated though sample runs on three industrial sheet metal parts. Knowledge base of the system can be modified depending upon the capabilities of a specific shop floor. Low cost implementation of the proposed system makes it affordable even for small scale stamping industries.

Acknowledgement

Authors thank Mr. Singh D, Manager, M/s D. D. Engineering, Pune, Maharashtra and all other domain experts for providing their expertise in development of the proposed system. Authors also acknowledge the sanction of the project on “Automation of design of compound dies for sheet metal industries” (File No. SB/S3/MMER/0061/2013) by the Science & Engineering Research Board (SERB), Department of Science and Technology (DST), New Delhi, Government of India.

References

1. *Kumar S and Singh R (2004), “A low cost knowledge base system framework for progressive die design”, Journal of Materials Processing Technology, Vol. 153–154, 958–964.*
2. *Nakahara S, Toshio K, Tamura K, Asuke F, Soda C, and Nakamura T (1978), “Computer aided progressive die design”, Proceeding of 19th Machine Tool Design Research Conference, London, 171-176.*
3. *Adachi M, Inoue K and Funayama T (1983), “Integrated CAD system for progressive dies”, Fujitsu Scientific and Technical Journal, Vol. 19 (2), 133-148.*
4. *Nee A Y C and Foong K Y (1992), “Some considerations in the design and automatic staging of progressive dies”, Journal of Materials Processing Technology, Vol. 29, 147- 158.*
5. *Nee A Y C (1994), “Some aspects of knowledge based approach for automating progressive metal stamping die design”, Computers in Industry, Vol. 24, 55-70.*
6. *Sing W M and Rao K P (1997), “Knowledge-based process layout system for axisymmetric deep drawing using decision Tables”, Computers ind. Engineering, Vol. 32, 299 – 319.*
7. *Lin B T and Hsu S H (2008), “Automated Design system for drawing die”, Expert Systems with Applications, Vol. 34, 1586-1598.*
8. *Hwang B C, Han S M, Bae W B, and Kim C (2009), “Development of an automated progressive design system with multiple processes (piercing, bending, and deep drawing) for manufacturing products”, The International Journal of Advanced Manufacturing Technology, Vol. 43, 644-653.*
9. *Kumar S and Singh R (2011), “An automated design system for progressive die”, Expert Systems with Applications, Vol. 38, 4482–4489.*
10. *Naranje V and Kumar S (2012), “Knowledge Based System for Selection of Components of Deep Drawing Die”, American Journal of Intelligent Systems, Vol. 2(2), 1-11.*
11. *Potocnik D, Pesan B, Balic J and Ulbin M (2011), “Intelligent system for the automatic calculation of stamping parameters”, Advances in production engineering and Management, Vol. 6(2), 129-137*
12. *Potocnik D, Ulbin M and Dolsak B (2013), “GAJA: 3D CAD methodology for developing a parametric system for the automatic (re) modeling of the cutting components of compound washer dies”, Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering), Vol.14 (5), 327-340.*
13. *Boljanovic V and Paquin J R (2006), “Die design fundamental”, Industrial Press Inc, New York.*
14. *Jones F D (1941), “Die Design and Die making Practice”, The Industrial Press, New York.*
15. *Smith D A (1990), “Die Design Handbook”, 3rd edition SME, New York.*
16. *Suchy I (2006), “Handbook of Die Design”, The McGraw-Hill Companies, Inc, New York.*
17. *Kashid S and Kumar S (2013), “An expert system for process planning of sheet metal parts produced on compound die”, Proc of 2nd International Conference on Industrial Engineering (ICIE 2013), SVNIT, Surat, India, 813-818.*

