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Computer aided system for parametric design of combination die

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Abstract. In this paper, a computer aided system for parametric design of combination dies is presented. The system is developed using knowledge based system technique of artificial intelligence. The system is capable to design combination dies for production of sheet metal parts having punching and cupping operations. The system is coded in Visual Basic and interfaced with AutoCAD software. The low cost of the proposed system will help die designers of small and medium scale sheet metal industries for design of combination dies for similar type of products. The proposed system is capable to reduce design time and efforts of die designers for design of combination dies.

1. Introduction

Combination dies are used for production of sheet metal parts having two or more operations in a single station. The terms compound and combination dies have frequently been interchangeably used to define one-station die. Compound dies are used for production of sheet metal parts having combined cutting operations like blanking and piercing, while combination dies are used where two or more sheet metal operations such as forming, drawing, extruding, embossing etc. are combined with each other or with the various cutting operations such as blanking, piercing, trimming, broaching, and parting off. Combination die (Figure 1) consists of several components including die block, die gages, stripper, stripper plate, punch (es), punch plate, back plate, blankholder, die-set and fasteners.

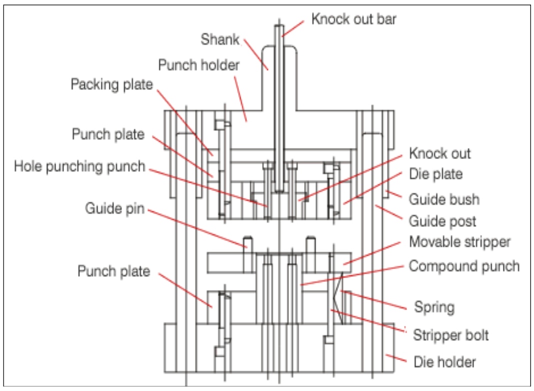

Figure 1. Typical Combination Die. [1]

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Design of combination dies is tedious, time consuming and skilled based activity. It requires highly experienced die designers and process planners. Many CAD softwares are available in market to aid die designers for design of dies. But these softwares does not have special die-design functions and capabilities. Furthermore, die designers have to use multiple software packages to perform various tasks of die design process. Also connectivity between these softwares is mostly non-existent. Further, because of high cost of these software packages, very few small scale industries can afford these. Also to operate these softwares and interpret the results generated by softwares well trained competent and experienced designers are required. These sofwares are only useful to improve design efficiency to some extent. Since 1970's and till date, researchers made a lot of efforts to develop computer aided die design systems for design of various types of dies used for production of sheet metal parts. A number of computer aided systems have been developed for punching, blanking, progressive, and deep drawing dies. Very few researchers tried to develop computer aided die design system for compound dies, and fewer research cover the combination die type. Therefore, there is a need to develop an automated system for quick design of combination die. Several researchers applied their efforts in developing computer aided design systems (CADD) for piercing and blanking die [2-6]. Many other researchers successfully developed CADD, knowledge based systems, Expert systems to automate the various tasks of progressive die design, such as [7-9] developed the system for strip layout, punch recognition, punch arrangement and complete design of the progressive die. Further worldwide researchers have also applied their efforts to develop automated systems for deep drawing die [10-13] and compound die [14-19], [20-22]. The foregoing literature review reveals that very few research efforts are found in the area of combination dies [23-27]. In this paper, a knowledge based computer aided system is presented for parametric design of combination die for cupping and piercing operations. The system is flexible and has low cost of implementation.

2. Design considerations

The classification of combinations die depends upon the types sheet metal operations accomplished in one stroke of the press [28]. Figure 2, shows a sample of the expected different types of combination dies from its individual operations.

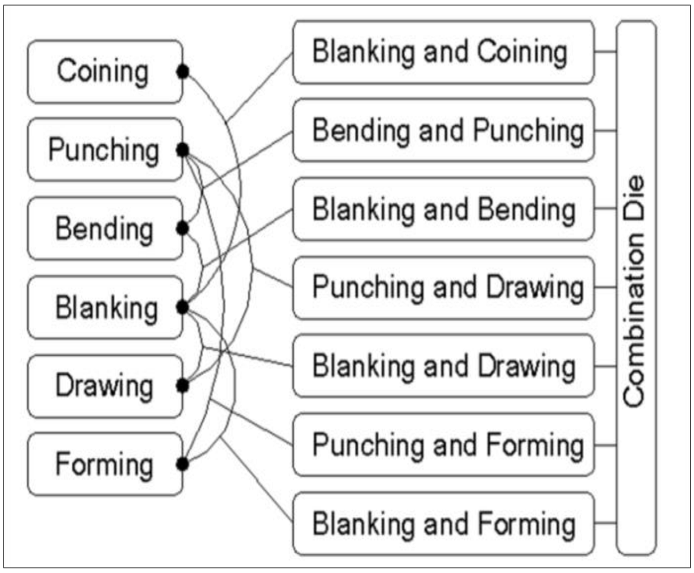

Figure 2. Classification of combination die.

The design, manufacturing and maintenance of these dies are very complicated. Traditionally design of combination dies is based on thumb rules. It involves number of tasks such as determination of cutting force, clearance between punch and die, thrust force, die clearance, force calculation, press tonnage requirement, determination of tool shut height, die block design, design of stripper plate, selection of stripper spring and stripper bolt, design of punch back plate, design of punch holder, design of punch holder, punch design, overall punch length, critical bucking force and critical length of the punch, compressive strength and deflection of the punch, design of guide posts and guide bushings etc. In most of the sheet metal industries, process planners and die designers use their rich industrial experience and knowledge to complete tedious and time consuming task of combination die design. Some of the important basic guidelines generally used for design of combination die are given as under:

1. The minimum thickness used for production of sheet metal parts in compound and combination dies is generally less than 0.4 mm.
2. In combination die for single stage drawing operation the sheet thickness should not be more than 1 mm.
3. All the design features that can be produced without danger or deformation should be pierced prior to wipe bending and forming.
4. Backup plates are made of hardened steel of 3/8 inch (9.5 mm) thick for general work, 1/2 inch (12.5 mm) thick for heavy duty jobs. The hardness should be in the vicinity of 40 to 50 HRC.
5. In the case of combined tool, spring loaded stripping system is used to accommodate bending operations.
6. The design of the die block basically depends up on the work piece size and thickness, the contour of the work piece and the die material.
7. Tool shut height should be kept 5-10 mm less than press shut height to provide a little height adjustment during press setting.
8. Compression type die springs are available in various service grades with corresponding permissible deflection ranges from 25-50% of the free length.
9. To prevent the bulging of the thin stock in combination die a channel type back guides in combination with front spacer and strip is used.
10. To perform two operations a ball bearing die-sets assembly, with guide-post sliding inside a ball bearing which is contained in guide bushing is recommended.
11. It is recommended that shank size should be selected according to the press tonnage and it should be made of medium strength steels with a hardness of 40 - 42 HRC.

Keeping in view of the above basic guidelines and recommendations, a computer aided system labelled as CADCD (Computer aided system for design of combination die) has been developed for parametric design of combination die for cupping and punching operations.

3. Development procedure of proposed system

The proposed system consists of two modules. First module is developed for determination of various process parameters. In the second module a rule based system is used for parametric design of combination dies for piercing and cupping operations. The system includes database that contains data of the mechanical properties of materials, die-set details etc. Initially system invites the user to enter part data information such as production quantity, tolerance, sheet thickness etc. through GUI at appropriate stages during a consultation. User interface of the proposed system is developed using Visual Basic 6.0 interfaced with AutoCAD software. In the first module, die design calculations executes for the die components dimensions. It is based on the relationships between the die components. Second module is developed to model the die components and die assembly of combination die for cupping and punching operations. The module takes required inputs in the form of size of die block, stripper fasteners etc. automatically from output data files generated during the execution of first module. It also takes the inputs from the die component database and part information data base. The proposed system has more than 200 production rules. These rules are coded in Visual Basics 6.0 and interface with AutoCAD. The design rules related to the cupping and punching die, can be simply classified to cutting rules and drawing rules. A sample of production rules incorporated in the proposed system is given in Table 1.

Table 1. A Sample of Production Rules Incorporated in the proposed System.

S. No.	IF	Then
1	Sheet material = Tin/Copper Brass/Stainless steel /Aluminum; and Design feature = Circular/Square/Rectangular/Oblong hole; and Minimum hole diameter/dimension in mm < 0.5	Set minimum diameter/dimension of circular / rectangular/square/oblong hole in mm = 0.5
2	Sheet material = Stainless steel [AISI 1090]; and Shear strength = 600-650 N/mm2; and Sheet thickness in mm > 3.0; and Sheet thickness in mm ≤ 4.0; and Hardness of sheet material = 50-55 HRC	Set clearance all around = 6.4 % of sheet thickness
3	Sheet metal operations= Piercing and drawing and material =Aluminum	Shearing Force = Ls x σs x T Where, Ls - Sheared length, mm; σs - Shear strength, N/mm2; T - Material Thickness, mm.
4	Draw Stage = First; and Diameter of first stage (di) Shell diameter (d)	Drawing Force, Fi $=\pi.d.t.\sigma y(\frac{D}{d} - 0.7)$
5	Sheet metal operations= piercing and drawing and material = mild steel	Stripping force (Piercing) = L x T x 20. L = Length of cut, mm; T = Material Thickness, mm
6	Material = Brass; and Type of press = Double action die	Set the drawing speed = 0.50 m/sec
7	Sheet metal operations= parting off and drawing Aluminium and mild steel	Stripping force (Parting off) =. Stripping force (Drawing) = 30% of Shearing Force X% of Drawing Force.
8	Size of blank in mm ≤ 25.0; and Sheet thickness in mm > 1.0; and Sheet thickness in mm ≤ 2.0; and Die material = Tool steel	Select width of die block in mm = (Strip width + 100.0); and Select length of die block in mm = (Strip length + 110.0)
9	Minimum tolerance required on part in mm ≥ 0.001; and Maximum tolerance required on part in mm ≤ 0.02; and Design feature = hole or slot or oval hole or internal contour cut	Required operation = piercing
10	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 + clearance between punch and die); 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
11	Minimum tolerance required on part in mm ≥ 0.001; and Maximum tolerance required on part in mm ≤ 0.02; and Design feature = hole or slot or oval hole or	Required operation = piercing

	internal contour cut	
12	Required sequence of operations = piercing and drawing	First operation = drawing and Second operation = Punching
13	Required operations = piercing and blanking	Upper punch = piercing; and Lower punch = blanking
14	Length of die block in mm > 200.0; and Length of die block ≤ 300.0 mm; and Width of die block in mm > 200.0; and Width of die block ≤ 300.0; and Tolerance on part in mm ≤ 0.005 Direction of feed of strip to the die-set = Parallel	Place die in the four pillar die-set with pillar having diameter of bush in mm = 26.0; and Bolster dimension in mm = 34.0; and Length of die-set in mm = 380.0 Width of die-set in mm = 350.0 height of die-set in mm = 28.0

4. Sample run of the proposed system

The sample run and validation of proposed system has been presented through industrial example components shown in Figure 3. User initially loads the system by using the GUI interface with AutoCAD. The system invites the user to enter part data information such as production quantity, tolerance, sheet thickness, sheet material, shear strength etc. through GUI as shown in Figure 4. The system stores these part data automatically in a data file labelled as PART.DAT. As soon as the user enters all required inputs, the system generates the drawings of die components and die assembly in the form of orthographic views and 3D views on AutoCAD screen which are stored automatically in drawing files. Figure 5a, 5b, 5c shows the 2D orthographic views of die component and die assembly automatically generated by the system modules for the example component and Figure 6a and 6b shows the 3D wire frame and 3D solid model of die component and die assembly for the example component. The system is parametric in nature, therefore user can easily modify these drawings through editing respective data files of die components or using AutoCAD commands directly. The system is tested for similar types of parts of different dimensions taken from sheet metal industries. The 2D and 3D drawings automatically generated by system module for component having more than two sheet metal operations are verified from experienced die designers and found very similar to those prepared by the die designers of stamping industries. The time taken by the proposed system for modelling of die components and die assembly for the example part is very less in comparison to the manual drafting and/or by using some CAD software. Notable features of the proposed system are its low cost and the linking of the die design process with quick modelling of die components and die assembly.

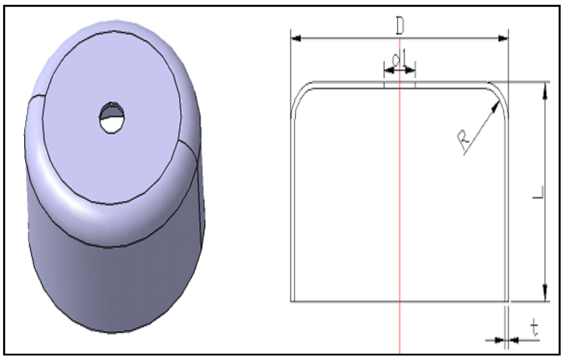

Figure 3. Example component (All dimensions are in mm); Thickness (t) =1mm, Diameter (D) = 99 mm, Pierced hole diameter (d1) = 10 mm, Radius (R) = 8mm, Length (L)=90mm.

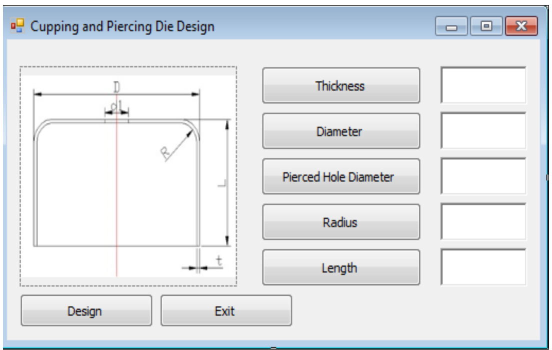

Figure 4. Graphic User Interface (GUI).

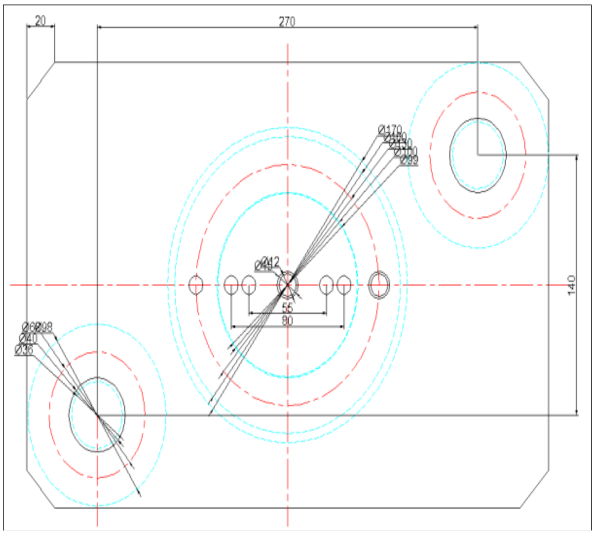

Figure 5a. Output of proposed system forexample component.

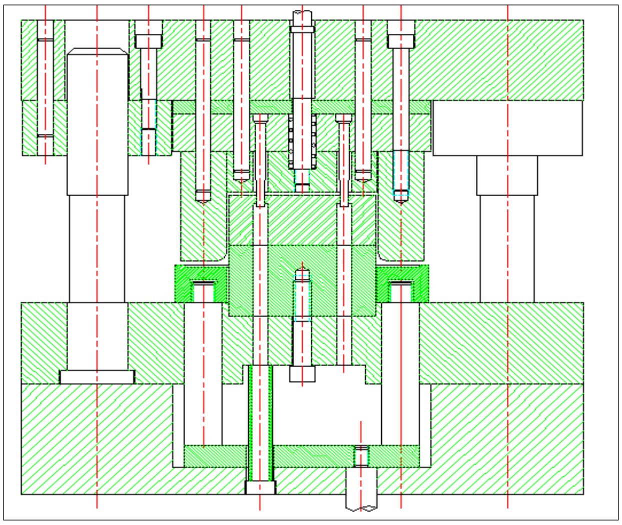

Figure 5b. Output of proposed system for example component.

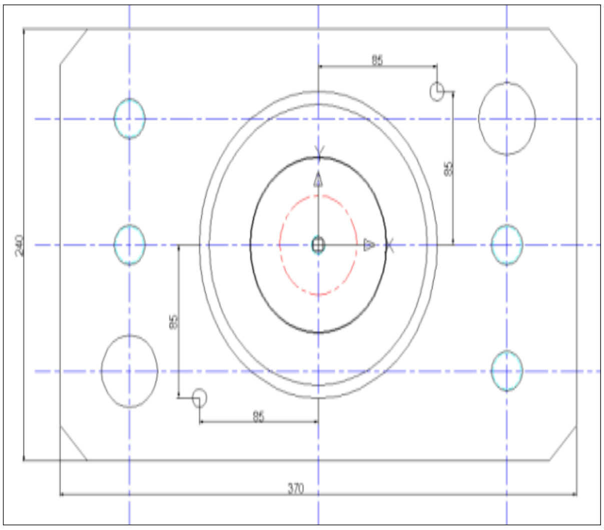

Figure 5c. Output of proposed system for example component.

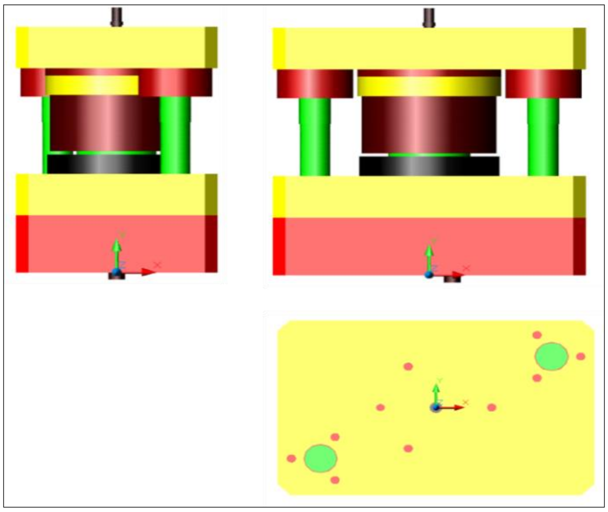

Figure 6a. Output of proposed system for example component in 3D solid mode.

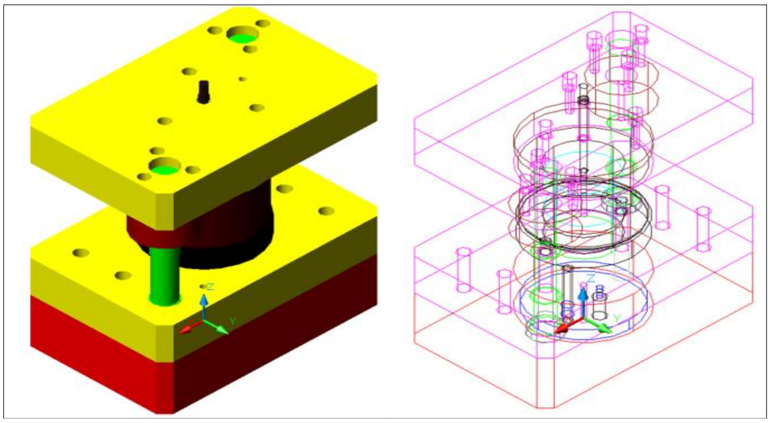

Figure 6b. Output of proposed system for example component in 3D wire frame and 3D solid mode.

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5. Conclusion

A knowledge based computer aided system for parametric design of combination die for cupping and punching operations has been developed. The proposed system is coded using Visual basic on AutoCAD platform. A novice engineer who may have little knowledge of die design can do the die design easily using the proposed system. With this system a significant reduction in design and modelling time from days to few minutes has been demonstrated in various industries. The low cost of implementation of proposed system makes it affordable for small and medium scale sheet metal industries. The outputs of the system in the form of dimensional drawings of die components can be used to create formatted data files which are acceptable by the CAM package for manufacturing the die components.

6. References

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