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Design and Analysis of Press Tools for a Thermostat Lever Component

[1]T. Paramesh , [2]R.SuvarnaBabu, [3]S. Amith Kumar

[1]Associate Professor in Mech. Dept., St.Martin's Engineering College, Dhulapally, Secenderabad, Telangana State

[2]Assistant Professor in Mech. Dept., St.Martin's Engineering College, Dhulapally, Secenderabad, Telangana State

[3]Assistant Professor in Mech. Dept., St.Martin's Engineering College, Dhulapally, Secenderabad, Telangana State

[1]tparamesh331@gmail.com , [2]rsuvarnababu@gmail.com, [3]shaneamith@gmail.com

ABSTRACT

Press tools are used to fabricate sheet metals into required shape by various press operations also called cold stamping. A device is used for punching out sheet metal components such as levers from the stock strip used in the lever mechanism of thermostat. A thermostat is a device automatically operates an electrical switching mechanism in response to sensed changes in temperature in response to the remote temperature sensor controller at which the switching mechanism is actuated in response to a certain movement of the lever mechanism. The prime objective of the paper is to design progressive and bending tools or dies that combines maximum production to produce the component and least maintenance with "lowest feasible cost, that exceeds the expectations of the customer in aspects like Quality, Cost, for the desired life. JDP TOOL TECH has got a project to design press tools for thermostat lever. This paper presents CAD analysis and design calculations for press tools for the thermostat lever mechanism.

1. INTRODUCTION:

Metal Stamping is the process of taking blank sheet metal of various thickness materials and forming into different shapes by different operations. Today's modern technology demands technique to produce quality products at an affordable price to gain an edge over competitors. Sheet metal stamping plays a major role in fulfilling the requirements of modern technology. The design of press tools by computer simulation will be highly beneficial to analyze process assessment capabilities & thereby saving lot of expenditures by avoiding repeated and costly tryouts now replaced many components which were earlier cast or machined. Material economy & the resultant reduction in weight and cost, high productivity, use of unskilled labor, & a high degree of possible precision have rendered presswork indispensable for many mass production goods such as electronic appliances, steel furniture, utensils, automotive and other manufacturing industries. For instance, the entire top of a car can be finished to size from a single sheet metal and there is no need for further machining as in the case of castings or forgings.

Design of thermostat lever involves the concepts of sheet metal cutting operations and designing dies for mass production to produce the component. It involves complete study on types of operations that are performed for shaping the sheet metals, dies, material and selection of springs. Shaping sheet metal in to finished lever involves determining the die cutting operations and making a sequence of those operations by studying the lever drawing, determining dies, designing the strip lay out and designing dies for the finished product. The design of metal stamping dies is a complex and highly specialized procedure and typically it takes 20% of the lead-time from the concept design to the final stamping manufacture. The diverse nature of products produced by stamping die demands a high level of knowledge on the part of the die designer that can only be achieved through years of practical experience. The knowledge gained by die design experts after long years of experience is often not available to others.

The Modeling and Assembly in all tool elements are done in CATIA V5. This involved making the modeling, drawings of assembly, drawing of individual tool elements etc. CATIA is a 3D modeling software for modeling & manufacturing of complicated shapes and parts. Advanced and sophisticated features of CATIA software enables to model the minute technicalities of the components with great ease. Die design is the preliminary stage in stamping die manufacturing once the product design is completed. Die design stage is very critical, a good die design can produce accurate components which can run for long time with less maintenance, it involves deciding the required stamping operations, basic layout, machining processes, type of stamping presses to be used etc. A die designer should have thorough knowledge about these elements to create a good die design. Computer aided design technology has developed really well during last decade to help die designers. Commercially available CAD/CAM systems are providing assistance in drafting and analysis in die design. With the advancement in the area of computer graphics, CAD/CAM and Artificial Intelligence (AI), some researchers started to exploit these techniques for the design of metal stamping dies. AI is the study of how to make computers perform intelligent things for the processing of unstructured scattered knowledge for the solution of complex problems.

2. LITERATURE REVIEW:

In order to develop better concurrency between design and manufacturing of metal stamping die, a stamp ability assessment or evaluation is necessary. As a first step in the planning for manufacture of a sheet metal part, it is useful to check its internal as well as external features for assessing its manufacturability on stamping die, such checks are useful to avoid manufacturing defects, section weakness, and need of new dies, tools or machines. De Sam Lazaro etal [1] Developed a Knowledge-based expert system using principles of group technology for multi-stage forming process for feature recognition, material selection, blank determination, optimum sequencing of operations, tool and machine selection. Nakahara et al. [2] Introduced a progressive die design system that

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examines the part design data to decide whether blanking can stamp it or not and they developed a knowledge-based system for identifying design rule violations to improve part manufacturability. Duffey and Sun. [3] From University of Massachusetts described a proof-of concept system for progressive die design for simple hinge part. The system was implemented using knowledge collected from manufacturability data, industry experts and standard die components; the system generates flat pattern geometry and develops a strip layout automatically. Shpitalni and Sadda.[4] Addressed the problem of automatic tool selection and bending sequence determination using graph search heuristics. Cheok et al. [5] From National University of Singapore have reported to develop an intelligent progressive die (IPD) design system. They used various AI techniques such as feature-based modeling, rule-based approach and spatial reasoning to work piece shape representation, shape recognition and decomposition, and die component representation for die design automation. Xie et al. [6] Developed a compound cutting and punching production method for small and medium size sheet metal industries. The system uses concurrent and global design and manufacturing environments by integrated data integration platform based on Pro/INTRALINK and STEP, and a knowledge-based real time CAPP (RTCAPP) system into existing CAD system. Prasad et al [7] Developed a computer aided die design system (CADDS).The system is capable to generate strip-layout automatically, conduct design checks for various die components, and generate the assembly views and bill of materials for the blanking die. This system is developed by interfacing AutoCAD with Auto LISP. Ismail et al. [8] worked on design automation for progressive piercing and blanking dies. Their work is based on applying a coding technique to characterize the stamped part geometric features, which is subsequently used to generate the type and layout of the die punches, and then developed the strip layout automatically. Dequan et al. [9] presented a comprehensive review of knowledge-based system used in stamping planning. They presented a framework of CAD system that carries out automated process planning for piercing operation of precision work at a high speed and also developed an integrated system using FEM simulation and artificial neural network (ANN) to approximate the functions of design parameters and evaluate the performance of die designs before die tryout. Kumar et al [10] Developed an intelligent system for selection of progressive die components. The system modules are capable to determine 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. This system is developed using rule-based approach of AI and it is coded in Auto LISP language. Gupta et al [11] described a process planning system for robotic sheet metal bending press. The system automatically determines bending sequences, selection of punches and dies and manufacturing costs etc. and gives feedback to improve the plan on operation-by-operation basis. Dequan et al [12] presented a comprehensive review of knowledge-based system used in stamping planning. They presented a frame work of CAD system that carries out automated process planning for piercing operation of precision work at a high speed.

3. DESIGN METHODOLOGY:

Systematic procedure followed for die making:

1. Study of Basics of Die making.
2. Analysis of the details of the component provided.
3. Study of material characteristics of the component
4. Listing the type of tools to be designed.
5. Blank opening up calculations of the component.
6. Force /Tonnage calculations
7. Designing and determining the dimensions of the individual parts of the tool.
8. 2- Dimensional and 3-Dimensional modeling of all the parts of the tools, assembled tools.
9. Preparing the final Bill of Material lists of the tools designed.

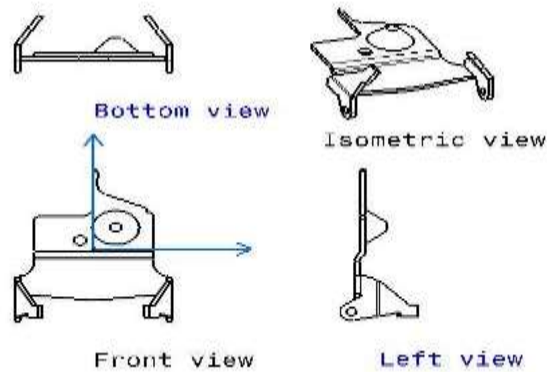

Fig.1: Thermostat Design

A thermostat is a device for automatically operating an electrical switching mechanism in response to sensed changes in temperature. Levers are used in the lever mechanism of thermostat. These devices have a sensing element positioned remotely from the electrical switching mechanism. An example would be devices having a remote sensing element for sensing freezing conditions in a device such as a refrigerator or freezer, with switching mechanism located exteriorly of the freezing compartment. The levers are made from CRCA STEEL- Low Carbon Steel Composition. The properties is observed in the below table.

Carbon % - 0.35 to 0.45	Physical Properties:
Silicon % - 0.10 to 0.35	Hardness: 170HV max
Manganese % - 0.60 to 0.90	Yield Stress: 270N/mm2 min
Sulphur % - 0.05 max	Tensile Strength: 590N/mm2 max
Phosphorus % - 0.05 max	Elongation %: 30 min

Due to low carbon content, this grade of steel offers better forming & bending quality. It is used for applications, where critical bending operations are required. These steel have good corrosion resistance, because of unique combination of strength & toughness after heat treat treatment.

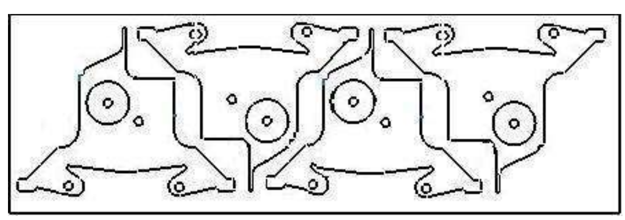

Fig.2: Strip layout

From the structure of the component, we analyzed that we need to design a compound blanking and piercing die for getting the specified contour of the component. Therefore the blank open calculations were being done and the strip layout was being designed. Based on the thumb rules generally followed by the industry for the design of these tools, blanking and piercing tool is designed, modeled in 2-D and 3-D.

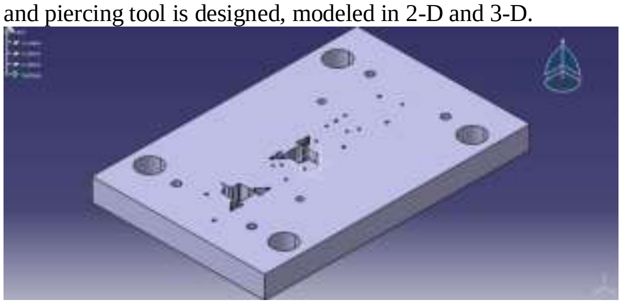

Fig.3 Bottom bolster

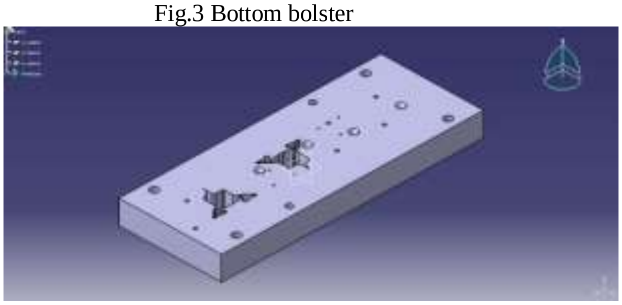

Fig.4 Die plate

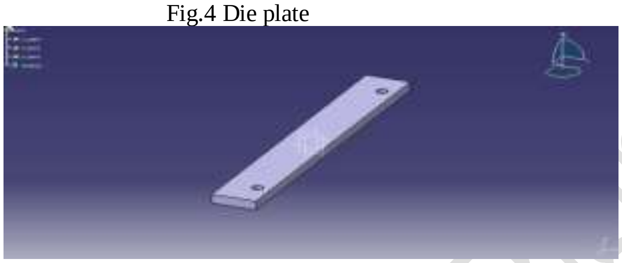

Fig.5 Guide plate

4. DESIGN CALCULATIONS:

To determine the Blank length, bend allowance 'P' is to be determined for each bend. The blank length is estimated as sum of lengths 'L' of the bend legs and the allowances. B = L1 + P + L2; where 'P' is called the bend allowance (= (R+C) 2*Π*N/ 360).

N = angle of bend

R = Bend radius (Internal radius need to be taken)

C = Distance from the inner surface to the neutral plane.

'C' is a variable factor depending largely upon the Ratio of stock thickness 'T' to the bend radius 'R'. Optimum value for 'C' may be considered to be, the dimensions of the blank obtained are always considered the tentative values and not the exact values as they may be changed as per the convenience after testing the forming tool operation on the blank which is tested.

1. Material- S.S-304 AISI-304
2. Thickness of the stock= 1.6mm
3. Component area=1045.522 mm2
4. % of strip used = (Area of component*4) / (length of strip*width of strip)
   = (598.29 *4)/(117. 9*30)
   % of strip used = 0.6842*100 = 68%

Shear force =K L t S_{sh} /1000 tons

Where K is a constant =1.1 to 1.5 (based on clearance)

L =length of cut in mm

t =thickness of stock in mm

S_{sh} =shear strength of material Kg/mm^2

5. Shear force = 1.5x1032.972x0.2x40/1000 =12.39tons.
6. Stripping force =10% of shear force
   =10x12.39/100
   =1.23tons.
7. Total force=shear force + stripping force
   =12.39+1.23
   = 13.6293tons
8. Press tonnage=1.2xtotal force
   =1.2x13.629
   =16.35tons
   =17tons.
9. Thickness of the die plate (td) = $\sqrt[3]{\mathbf{F_{sh}}}$
   Where F_{sh}=shear load in tons
   td = $\sqrt[3]{12.39}$
   = 2.314cm
   = 24mm
   Die thickness selected =24mm
10. Thickness of the punch holder=0.5xtd
    =0.5x24
    =12mm
11. Thickness of bottom plate (tb) = 1.5xtd
    =1.5x24
    =36mm
12. Thickness of top plate (tp) =1.25xtd
    =1.25x24
    =30
    Thickness of top plate selected =30mm
13. Thickness of stripper plate (ts) =0.5xtd
    =0.5x24
    =12mm
    Thickness of stripper plate selected=12mm
14. Cutting clearance =4% of sheet thickness
    =0.04xo.2
    =0.008mm/side
15. Blank punch size=size of blank die -2 c
    =27.6-2x0.2x6/100
    Where, c=6% of thickness of wall
    =27.6-0.024
    =27.576mm
16. Cutting force=Tl x D x t x fs
    =3.14x29.1x0.2x40
    =735.65 N

Blanking die:

Δ= FL^3 / (192E I)

F= 80%OF CUTTING FORCE = 0.8* 735.65N = 588.2 N

L=312

E=210000MPa=2.1*105N/MM2

I=bh^3 / 12 b=122mm, h=30mm.

I=122*27000 / 12 = 274500.

Δ= 588.52 * 312^3 / 192* 2.1* 10^5* 274500

=0.001614961 = 16.14μm = 0.01614* 10^-6 mm

STRESS: DIE BLOCK

σ = F/A = 588.52 / 122*30 = 0.1607978 N /MM^2

Bending punch:

S cn=cutting force / cross sectional rea of punch
P b= 123.1 N
A=28*60*53 mm^2 E=2.1*10^ N/mm^2
L=60 mm.
Depth =53, breadth=28
S cn=123.1 / 89040. =0.00138=13.8*10^
Δ= FL^3 / (192E I)
L=60 mm.
Δ=0.18364 mm

Stress: Bending Punch
σ = F/A = 588.52 / 28*53 = 588.52 / 1484 =0.3976486 N /MM^2

Bending calculations:
Bending force of "U" bending
Fb = $(C \times bs^2 \times \sigma)/w$
= 1.026×4.176×400/30
= 64.514mm
Punch radius = 2.72m
Die punch = 2.72S
= 2.72 × 0.2
= 0.544
Where
C = constant; B = width of bend; S = sheet thickness; σ = ultimate tensile stress; R1 = Die Radius; R2 = Punch Radius;
Bending force = $(C \times bs^2 \times \sigma)/ 2(R1+C_b+R2)$
C_b= bending clearance
$W/2 = R1+R2+C_b$
$30/2 = 2.72+.544+ C_b$
C_b =4.595
Bending force = $(C \times bs^2 \times \sigma)/ 2(R1+Cb+R2)$
= (1.026×4.716×400)/2(0.544+4.595+2.72)
= 123.13 N
Pressure = Force/Area
= 123.13/1440
= 0.0855N/mm^2

5. STRUCTURAL ANALYSIS:

Blanking punch (die block):
Material S.S-304
Material properties:
E=210000Mpa
Poisson's Ratio= 0.33
Density = 7850Kg/m^3= 0.00000785 Kg/mm^3
Analysis Procedure:
Set Units - /units, si, mm, kg, sec, k
File- change Directory-select working folder
File-Change job name-Enter job name
Select element-Solid-20 node 95

Bending Punch
Material S.S-304
Material properties:
E=210000Mpa
Poisson's Ratio= 0.33
Density = 7850Kg/m^3= 0.00000785 Kg/mm^3
Analysis Procedure:
Set Units - SI, mm, kg, sec, k
File- change Directory-select working folder
File-Change job name-Enter job name
Select element-Solid-20 node 95

Structural Analysis of Blanking Die:

Material	Displacement(mm)	Stress(N/mm^2)	Deflection(mm)
S.S	0.279E^{-05}	0.491673	0.348E^{-06}

Structural Analysis of Bending Punch

Material	Displacement (mm)	Stress(N/mm^2)	Deflection(mm)
S.S	0.157e^{-05}	0.213643	0.149e^{-06}

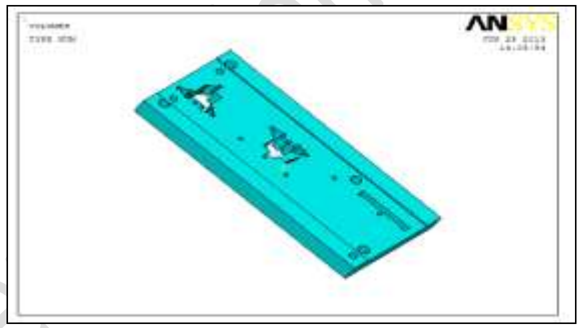
Fig.6: Imported model

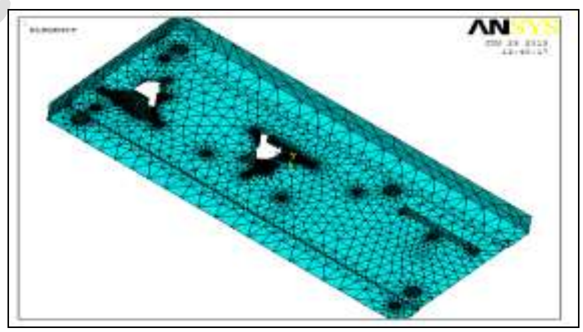
Fig.7: Meshed model

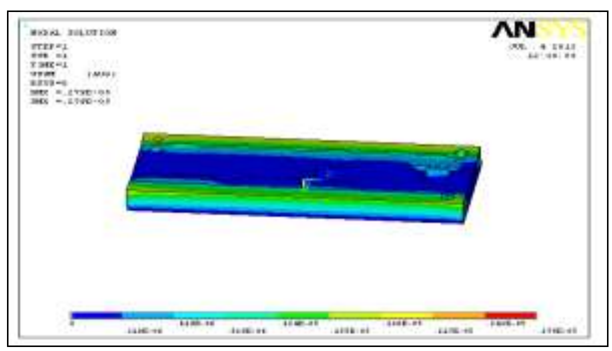
Fig.8: Finished model

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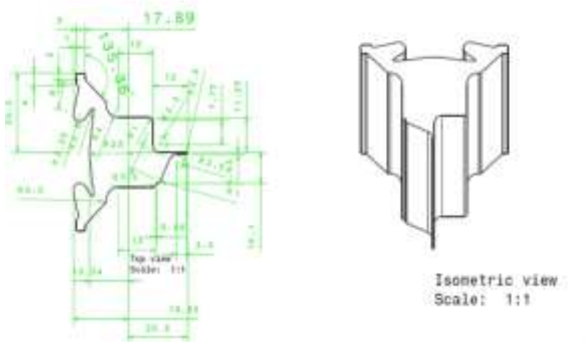

Fig.9: Blank punch

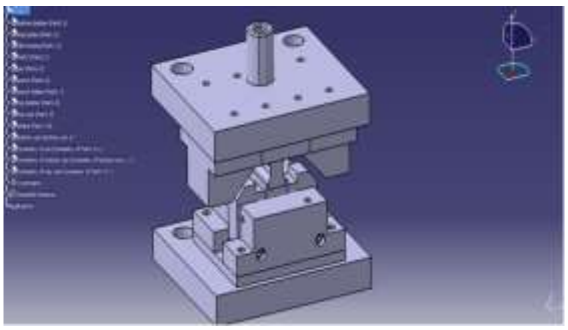

Fig.10: Bending die assembly

RESULT AND DISCUSSION

The successful manufacture of the designed progressive dies for the lever component of thermostat used for refrigerator as for the designed parameters which have been analyzed for deflections, stress and strain values for both theoretical and software analysis as well at any results of stress and strain.

Part Name	Die Plate		Analysis Result	
	Stress	Deflection	Stress	Deflection
Die plate	0.1607978	0.016e-06	0.49163	0.348e-06

The table indicates safe design with the result of the software which is accurate as taken fine meshing for an analysis. But in theoretical analysis the approximate values nearer to the software values and calculated press tonnage is 17 tons.

CONCLUSIONS

The individual components of progressive tool were modeled in CATIA V5-R21. Each individual file was imported to Ansys12.0 software through Initial Graphics Exchange Specification (IGES) format. The following conclusions were made.

1. The results obtained through analysis are approximately nearer to the theoretical values. This demonstrates that the analysis carried out was correct.
2. It is also observed that the design of progressive tool is safe as all the stress values were less than the allowable stress of the material.
3. Forces are calculated when blanking and bending operations are done. The press tonnage calculated is 17tons, force to shear is 12.39tons, and stripping force is 13.6293tons.
4. The pressure produced while banking is 0.102N/mm2 and while bending is 0.0855N/mm2.

Scope of future work:

Therefore, there is need to develop an intelligent system by combining some suitable AI technique and CAD system for manufacturability assessments/reasoning, concurrent planning and quick design of multi-operation dies. The system must have rich knowledge-base comprising knowledge of experienced die designers and process planners, must be interactive and user friendly and have low cost of implementation. The system finally must give its output in form of drawings of strip-layout, die components and die assembly. The authors are applying their research efforts in this direction to assist process planners and die designers of small and medium scale sheet metal industries.

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