International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 05 | May 2022 www.irjet.net p-ISSN: 2395-0072

Design and Development of Press tool used for the Manufacturing of Intercooler Mounting Bracket

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Abstract - *Press tools are used to produce a particular component in large quantities, out of sheet metals where the particular component achieved depends upon press tool construction and its configuration. Blanking, bending, piercing, forming, drawing, cutting off, parting off, embossing, coining, notching, shaving, lancing, dinking, perforating, trimming, curling and other operations are performed using various types of press tool structures.. The Current Progressive die that is being used in the concerned industry performs 3 operations namely: Punching, Sorting, and blanking for the production of the Intercooler Mounting Bracket. These operations are being performed simultaneously i.e., firstly Punching on the sheet metal strip, then sorting it into the correct position for the next operation i.e., Blanking which is the final operation that is performed on this die. As it performs these operations simultaneously, the time taken to get the final product is comparatively more. This also affects the overall production rate, time cycle, and the profit made from this product*

Key Words: Compound Die, Piercing, Blanking, Material Selection, Die Design, Modelling

1.INTRODUCTION

Many industries use sheet metal cutting as a major production step. Nowadays, its importance has become more pronounced due to the advancement in technology. Dies are generally customized to the item they are used to produce which range from simple paper clips to complex pieces used in advanced technology.

Compound dies are widely used in sheet metal industries for the manufacturing of pierced blanks with good accuracy. To carry out tasks efficiently and productively, industries demand high-quality compound dies with a long life. Two or more than two operations can be performed in compound dies and are thus more complex compared to other sheet metal dies such as progressive, bending, drawing, etc. It involves various components such as punches, strippers, die sets, die blocks, knockout bars, dies gauge, etc.

Therefore, Die design is a complex subject and a large part of tool engineering. Thus the design of dies is done considering key thumb rules and past experiences of the people working in the industry.

1.1 Types of Operations performed in compound dies:

A compound die performs only cutting operations (usually blanking and piercing) which are completed during a single press stroke.

1. Blanking: Blanking is a sheet metal cutting or shearing process in which the part that is cut from the strip is the required product. In blanking, the die size is equal to the diameter of the blank and the punch is made smaller by subtracting the clearances from the die size.

2. Piercing: The principle of the piercing process is similar to that of the blanking process, the only difference is that here the required part is the strip on which the piercing is done. The difference between the blanking and piercing. The die and punch size differs for the piercing and blanking operation. For piercing, the punch size is made equal to the size of the hole to be pierced while the die is made larger by adding the clearance.

1.2 Problem Definition

Design a compound die for the production of intercooler mounting bracket of CR material as follows:

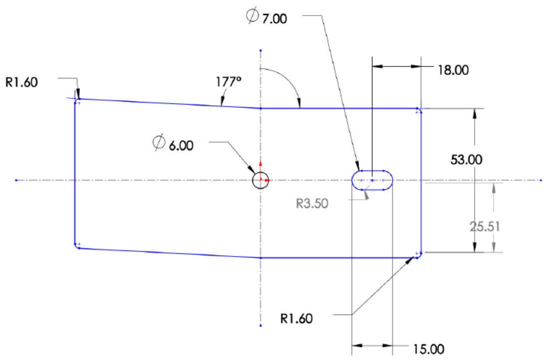

Fig-1: *intercooler mounting bracket*

2.LITERATURE REVIEW

A literature review within a specific field of interest of research is one of the most essential activities in the process of research. This section acts as a platform for the whole research to support and define each action performed during analysis and experiment. Different books, research papers were studied to collect the basic information and design procedures according to standards.

S.B. Gaikwad et al [1] discussed in their paper "Design and Development of compound die" (2019) that the project mainly focuses on compound die design for existing operations to replace the current progressive die wherein the die contributed to increasing in the production rate, reduction of production cost and the time cycle from 30 to 40 sec using suitable design being done in Solid works and Analysis of the press tool being done in Ansys

Pawan Kumar Rai et al [2] in "Causes & Prevention of Defects (Burr) In Sheet Metal Component" (2013) has discussed the imperfections that are common in the sheet metal industry which after a specified limit it takes the form of defect. Also different Chances of failure in Manufacturing & Assembly of Tool, need of material hardness, clearances and alignment of components are discussed.

Gaurav C. Rathod et al [3] in "Study and Analysis of Press Tool Design" develop a press tool for Piercing and notching made for sheet metal component. It shows a study of force reduction method used while designing the die and to ensure excellent geometrical compatibility of the mechanical press and the designed combined press tool. They also discuss a detailed study of various materials to be used for different components of the die, depending upon their importance, the efficiency of the die and the various factors affecting them.

M Subramanian et al[4] in "Design and Analysis of Press Tool to Produce Radiator Stay Bracket" (2016) mostly focus on the designing of press tool to be used in the production of the stay bracket, also modelling of all the components, and analyzing the stress and deflection on the components.

In "The design and fabrication of a compound die to make hexagonal washer" the authors N. JYOTHIRMAYI et al [5] presented the design and fabrication of a compound die that combines blanking and piercing operations. Detailed calculations for Press capacity, plate thickness, Punching, and blanking forces as well as spring calculations were shown. The successfully designed die is being currently used in the Metal forming Lab of Chaitanya Bharathi Institute of Technology, Hyderabad.

2.1 Inferences from Literature Review

The detailed literature review revealed that even though press tools have a large impact on the tool industry very few academic researchers are engaged concerning this topic. With the continuous development of the industry, higher and higher requirements are placed on the press tools. Therefore, the demand for the development of precision, large-scale, complex, long-life tools exceeds the total development speed thus the most common problem that could be found in this area is the overall accuracy and efficiency the tool must provide. The most common cause for this problem was found to be the non-uniform application of force on the die which further produces a slight amount of bend formation or burr formation on the final product as well as the development of an unwanted gap between the punch and die plates which further reduces the life of the die. One of the ways to prevent this is to minimize the stress that will be produced in the die plate component of the press tool.

3.OBJECTIVE

The project's goals include increasing productivity, reducing human effort, reducing cycle time, lowering labor costs, designing blanking and piercing die, and developing blanking and piercing die. Product manufacturing competence among the masses is improved.

4.DIE DESIGN

4.1 Calculations

Operations:

Punching hole = ϕ 6mm
Punching capsule = ϕ15 mm
Blanking Area = 6586.23 mm^2

Punch and Die Size:

C clearance per side
C = $C*t*\sqrt{(\tau_{max}/10)}$
Where, C=Constant
C=0.005 (very accurate component);
C= 0.01 (normal component)
t =Sheet Thickness = 1.6 mm
$C = 0.01 * 1.6 * \sqrt{(360/10)}$ ... ($\tau_{max\ (HCHCR)}$=360 N/mm^2)
= 0.12 mm per side

Calculations

STRIP LAYOUT AND ECONOMY FACTOR:

Scrap Bridge S = 1.2 * thickness
= 1.2 * 1.6 = 1.92 mm
Pitch P = 57.291 mm
Width W = 132.686 mm
Area A = 6586.23 mm^2
Number of Rows N = 1

ECONOMY FACTOR = A * N * 100/ P * W
= 6586.23 * 1 * 100 / 57.291 * 132.686
η= 86.641 %

The proposed stock strip layout has a material utilization of 86.641%. As it is greater than 70%, it is accepted.

DIE CLEARANCE CALCULATION:
Clearance per side = 0.12 mm per side

PUNCH AND DIE CALCULATION:
Blanking operation = Component Size – 2(Clearance)
WIDTH = 53 – 2(0.12) = 52.76 mm
LENGTH = 127.96 – 2(0.12) = **127.72 mm**
Piercing operation = Component Size + 2(Clearance)
PUNCHING HOLE = dia. 6 + (0.12 * 2) = **6.24 mm**
PIERCING CAVITY = dia. 7 + (0.12 * 2) =**7.24 mm**

CUTTING FORCE (F_{sh}) :
Cutting Force = L * S * τ_{max}
Where, L = Peripheral length of profile to be cut in mm
S = Sheet thickness in mm.
τ_{max}= Ultimate shear stress in N/mm^2
Total cutting periphery = 415.84 + 38 + 18.7 = 473 mm
τ_{max} (cold rolled sheet) = 2764 N/mm^2
So, CUTTING FORCE, F_{sh} = 473 * 1.6 * 276
= 208673.664 N = 21271.53 kg
= **21.2753 Tonnes**

PRESS TONNAGE :
PRESS TONNAGE = 1.2 * F_{sh}
= 1.2 * 208673.664
= 25.525 tonnes
= **26 Tonnes**

STRIPPING FORCE (F_{st}):
FORCE APPLIED ON STRIP PLATE
Fst =10 % OF CUTTING FORCE

So, stripping force in this case,
Fst = 10 % OF 208673.664
= **20867.367 N**

STRENGTH OF BOLT
= Stripping Force / No. Of Bolts
= 20867.367 / 6
= **3477.8945 N/ BOLT**

TOTAL FORCE REQUIRED
Ft = Fsh + Fst
Where,
F_{sh} = Shear force.
F_{st} = Stripping force.
So,
Total force, Ft = 208673.664 +20867.367
= 229541.031 N
= 23.398 Tonnes
= **24 Tonnes**

TOTAL MACHINE TONNAGE REQUIRED:
Considering 20% safety factor,
F = 1.2 * Total force
Total machine tonnage = 1.2 * 24
= 28.8 Tonnes
= **29 Tonnes**

Hence,
Thickness of Die Plate [$T_{die\ plate}$] = 3 √ Fsh
= 29.624 mm
= **30 mm**
Thickness of Top Plate = 1.5 * $T_{die\ plate}$
= **45 mm**
Thickness of Knockout Plate = 0.5 * $T_{die\ plate}$
= **15 mm**
Thickness of Top Punch Holder Plate = 0.75 * $T_{die\ plate}$
= **22.5 mm**
Thickness of Stripper Plate = 0.75 * $T_{die\ plate}$
= **22.5 mm**
Thickness of Bottom Punch Holder Plate = 0.75 * $T_{die\ plate}$
= **22.5 mm**
Thickness of Bottom Plate ...($\tau_{max\ (CRCA)}$=276 N/mm^2) = 2 * $T_{die\ plate}$
= **60 mm**
Thickness of Top and Bottom Back Plate = 0.5 * $T_{die\ plate}$
= **15 mm**

4.2 Material Selection

Material selection is the first step in designing any physical component. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals.

The materials selected for die and punch as follows:

- **OHNS:** Oil Hardening Non-Shrinkage Die steels are mainly used for short run tooling for cold forming dies, blanking dies, and cutting tools operating at ambient temperature.

Chemical Composition:

Table No-1: *Chemical Composition of OHNS Steel*

Element	Content (%)
C	0.95
Mn	1.1
Cr	0.6
W	0.6
V	0.1

Mechanical Properties

Table No-2: *Mechanical Properties of OHNS Steel*

Ultimate Strength	1000 (N/mm2)
Hardening Temperature	790-820°c
Maximum Hardness	60-64(RC)
Wear resistance	Medium
Machinability	Good

- **MS:** Mild steel **(**iron containing a small percentage of carbon, strong and tough but not readily tempered**)**, also known as plain-carbon steel and low-carbon steel, is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications.

Chemical Composition:

Table No-3: *Chemical Composition of MS Steel*

Carbon	0.16-0.18%
Silicon	0.40% max
Manganese	0.70-0.90%
Sulphur	0.040% max
Phosphorous	0.040% max

Mechanical Properties

Table No-4: *Mechanical Properties of MS Steel*

Max stress	400-560 N/mm^2
Yield stress	300-440 N/mm^2 min
0.2 % proof stress	280-420 N/mm^2 min
elongation	10-14 % min

- **HCHCR(D2):** HCHCR is an air hardening, high-carbon, high-chromium tool steel. It has high wear and abrasion resistant properties. It is heat treatable and will offer hardness in the range 55-62 HRC, and is machinable in the annealed condition. D2 steel shows little distortion on correct hardening. D2 steel's high chromium content gives it mild corrosion resisting properties in the hardened condition.

Chemical composition

Table No.-5:*Chemical Composition of D2 Steel*

Element	Content (%)
C	1.5-1.75
Mn	0.2-0.4
Cr	11
W	0.4-0.5
V	0.1

Mechanical Properties

Table No-6: *Mechanical Properties of D2 Steel*

Ultimate Strength	1020(N/mm^2)
Hardening Temperature	790-820 °C
Maximum Hardness	55-62(RC)
Wear resistance	High
Machinability	Poor

4.3 Experimental Setup

To satisfy the desired objectives, the experimental layout has been set up and trials have been performed to test the developed algorithm. This chapter covers in-depth details of the experimental setup, procedure and results observed. Different trials have been performed on different objects of different materials.

Progressive die stamping is a metal forming process widely used to produce parts for various industries, such as automotive, electronics, and appliances. Progressive die stamping consists of several individual workstations, each of which performs one or more different operations on the part. The part is carried from station to station by the stock strip and is cut out of the strip in the final operation.

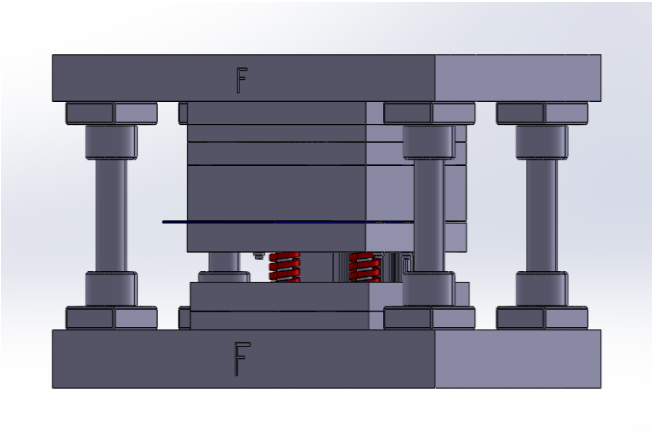

Fig-2: Compound die setup

4.4 Working

In the compound die, two operations are performed at the same time in one stroke of motion, i.e., piercing operation and blanking operation on the same station to yield the final product. But as two operations are being performed at the same time, there is no way to extract the final product without causing harm to the worker or obstructing the overall operation. Thus, a need to ensure the proper removal of the product occurs. This is fulfilled by using the knockout operation, where after the blanking and punching operations, the part gets attached to the buffer pad and can be carried out of the tool. Thus, removal of the product takes place.

The compound die can be separated into two assembles, namely the top assembly and the bottom assembly. The top assembly consists of top plate, knockout plate, top punch back plate, die plate, punch plate, buffer pad and most importantly, the top punches i.e., piercing punch and capsule punch. The bottom assembly consists of the stripper, stripper plate, blanking punch, bottom punch holder, bottom back plates, bottom plate and springs. The guide pillars and guide bush help in the proper orientation of both the assemblies and ensure proper working of the compound die so as to get the exact required product.

Fig-2 depicts the die as it appears during the operation, where the top assembly and bottom assembly is in contact with each other and the operation of piercing by the top punches and blanking by the bottom punches takes place. The top assembly is in motion, on which the press ram applies the required force, and the descending motion is initiated.

While the top assembly is now ascending upwards, the final product gets attached to the buffer pad, where after reaching a certain position the knockout pin pushes the knockout pad, which creates an impact on the buffer pad upon which the product is attached, and thus due to sudden shock, the product fall down and is ejected from the tool. All of these operations take place in just one stroke of motion.

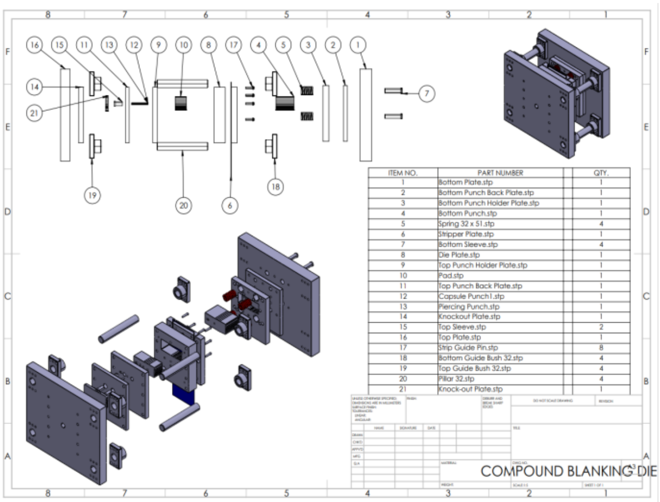

Fig-3: *Final Compound Blanking Die*

CONCLUSION

- Successfully designed the press tool to perform blanking and piercing die operations.
- Analysis and theoretical calculations when compared show a significant amount of similarity, thus validating the die design.
- By choosing the appropriate material for die, punch, and other parts, the tool life could be increased for maximum range.
- Ensures less fatigue and required skill to the operator due to fewer amounts of movement and thus saving time.
- Reduction in Production and manpower cost.
- A one-time investment in the requisite equipment would ensure a long-term supply of superior quality products, generating huge profits for the manufacturers.

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