MULTI-PURPOSE COMPOUND DIE DESIGN: A CASE STUDY

*[1]USMAN JIBRIN RUMAH,[2] ABDULMALIK MUSA GUSAU AND [3]MOHAMMED SULEIMAN LIMAN

[1,2]Department of Mechanical Engineering, College of Engineering, Kaduna Polytechnic, Kaduna State, Nigeria. [3] Department of Agric Engineering, College of Engineering, Kaduna Polytechnic, Kaduna State, Nigeria.

Abstract

Compound die is a single-hit dies that blanks and perforates a part at the same time in the same station. It is one of the cold working processes of sheet metal where components in Mechanical industry are manufactured. This paper presents a design of a compound die for mass production of drum/blower plate, by combining blanking and piercing operations.

Keywords: *Compound die, Mass production, blanking*

Introduction

Whenever sheet metal or other material is worked on a press, press tools are used. Press tools are special tools custom built to produce a component mainly out of sheet metal. Press tool is of stampings including cutting operations (shearing, blanking, piercing, etc.) and forming operations (bending, drawing, etc.). Sheet metal items such as automobile parts, (roofs, fenders, caps, etc.), components of air craft, parts of business machines, household appliances, sheet metal parts of electronic equipment's. Precision parts required for homological industry etc., are manufactured by press tools.
(Parmindersigh, Chirag, Bharat, & Sana, 2014)

The evolution of products, dictated by the necessity to survive in the market, requires changing in manufacturing processes. This requires an integrated approach of constructive aspects, technological, organizational and management of the development stages in order to reduce as much as possible time and cost of the new products. Design activity has an important role in developing a new product.

Compound die design is applied to dies in which two or more cutting operation, typically piercing, blanking and drawing are performed in the same single station and completed during the single press cycle. There are many ways to design a compound die, but since there is no place for the finished part to go during a compound die's operation, the part must be pushed back into the scrap web such that it can then be carried out of the tool and extracted in one or another fashion later in the die cutting operation. (Sneha & Dalu, 2012)

According to Bhaskar & Mahesh (2016), the factors must be considered in die designing like type of material, thickness of material, length of stroke, cutting area, clearance between die and punch. For designing of dies and punches special hard materials are used to enhance the life of tooling. The initial cost of tooling is more while press manufacturing requires very low running cost. Proper selection of die material is important, to avoid the un-necessary wear of dies.

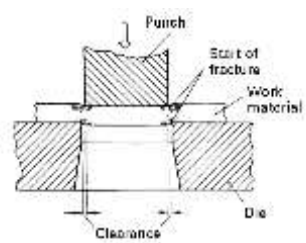
Advantages of a compound die system, first and foremost being the high and unsurpassed mechanical accuracy of a single step process. A second advantage of a compound die set up is its throughput. Because all internal and perimeter features of the part are created in one cycle. That means that if a strip is designed to create 10 parts, these 10 parts will be created in 10 press strokes. (Sneha & Dalu, 2012)

Objective

To design a compound die for mass production of drum/blower plate for mass production of post harvest processing machines parts, by combining blanking and piercing operations.

Theoretical Background

In blanking and piercing operations the work material, placed in the press tool, is cut by a shearing action between the adjacent sharp edges of the punch and the die. As the punch descends on to the material, there is an initial deformation of the surface of the material followed by the start of fracture on both sides, as in Fig. 1. As the tensile strength of the material is reached, fracture progresses and complete failure occurs (Black J. , 2004).



(Bojonovic, 2004)

Figure 1: Shearing action of punch and die

The major variables in blanking and punching are the punching force, F, the speed of the punch, the surface condition and materials of the punch and die, the condition of the blade edges of the punch and die, the type of lubricant, and the amount of clearance between the punch and die (Bojonovic, 2004).

According to Ghosh and Mallik (1986), optimum clearance and penetration of the punch can be obtained using equation 1 and 2 respectively blow:

$$\frac{t}{C_o} = 1.36\exp\ (\epsilon_r)\frac{2.3\exp\ (\epsilon_r)-1}{2\exp\ (\epsilon_r)-1} \ldots\ldots\ldots\ldots\ldots\ 1$$

$$\frac{\Delta + C_o}{t} = \frac{1}{2.45}\left[\frac{1.9\exp\ (\epsilon_r)-1}{2.56\exp\ (\epsilon_r)-1}\right] \ldots\ldots\ldots\ldots\ldots\ 2$$

The values of optimal clearance (C_o) and penetration depth ($\Delta+C_o$), in terms of the thickness of the workpiece (t), for various values of ε_r are calculated from equation (1) and (2), respectively.

The work required for punching operation can be expressed as:

$$W = \frac{1}{2} X F_{max} p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3$$

Where p is the depth of penetration = $\Delta + C_o$

Another important aspect of the blanking operation is to minimize the scrap by an optimum layout design (also known as nesting). This is schematically represented in figure 2. The minimum gap between the edge of the blank and the side of the strip is given as

$$g = t + 0.015h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 4$$

Where t is the thickness of the strip and h is the width of the blank. The gap between the edges of two successive blank (b) depends on the strip thickness t.

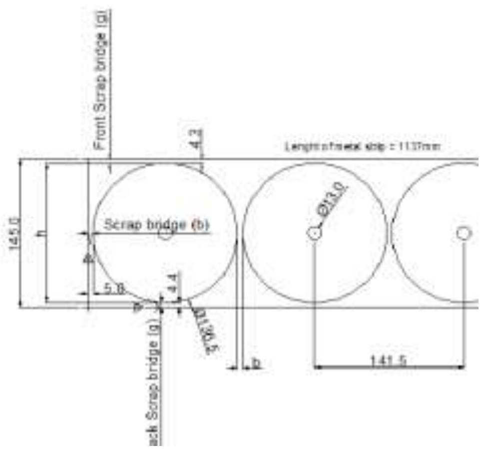


Figure 2: Scrap minimization by optimal layout

Economy of any strip layout in percentage is found out according to Krasugir (2009), by the following formula:

$$\boldsymbol{Economy\ factor\ (E)\ in\% = \frac{(\text{Area of the blank} \times \text{number of raws} \times 100}{(\text{width of the strip} \times \text{Pitch}}} \ldots\ldots\ldots\ldots\ 5$$

Die block thickness: The minimum thickness of the die block depends on type and thickness of sheet metal to be operated. The thickness can be obtained from

i) perimeter of blank,
ii) sheet thickness and
iii) Shear strength of sheet.

According to one thumb rule, the die thickness may be obtained as follows:

i) Die thickness = 20 mm, for blank perimeter ≤ 75mm
ii) Die thickness = 25 mm, when blank perimeter lies between 75 mm to 250 mm.
iii) Die thickness = 30 mm, for blank perimeter > 250mm

Spring loaded stripper or pressure pads is employed in applications where it is desirable to keep the stock flat during punching or blanking operation, and for better visibility of die block and stock before the commencement of the punching action. . The following empirical equation may be used to obtain thickness of stripper:

$$\boldsymbol{ts = \frac{1}{8}\left(\frac{w}{3} + 16t\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 6$$

(Das, nd)

Table 1: Ultimate Tensile Strength of blank

(Gupta & Khurmi, 2005)

According to NTTF (2005), Cutting or blanking force (F_1) is calculated using:

Material		(GPa)10^9N/m^2	(MPa) 10^6N/m^2	(MPa) N/m^2
Steel, Structural ASTM-A36		E 200	UTS 400	Y 250

$$\boldsymbol{F1 = length\ of\ the\ periphery\ x\ sheet\ thickness\ (mm)\ x\ shear\ strength}$$
.. 7

Stripping force (F_2)

$$\boldsymbol{F_2 = 10 - 20\ \%\ of\ cutting\ force}$$

$$\boldsymbol{F_2 = \frac{L \times s \times \tau S}{10} = \frac{F_1}{10}} \text{ .... } \mathbf{8}$$

Total force (F)

$$\boldsymbol{F = F_1 + F_2} \text{ .... } \mathbf{9}$$

Die plat thickness (DPT)

$$\boldsymbol{DPT = Cubic\ root\ of\ F} \text{ .... } \mathbf{10}$$

Case Study- Die Design Calculations

The case study presents here the design and development the "**threshing drum side plate"** that can be used on threshing drums of agricultural machineries. Blanking and Punching are required to produce the component. Detailed design procedure is given below:

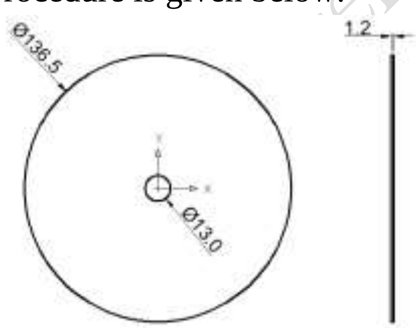


Figure 3: 2D View of Drum Plate

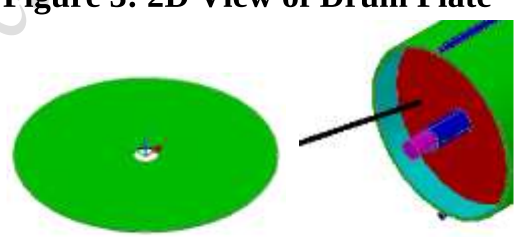


Figure 4: 3D View of Drum Plate

Table 2: Properties of ASTM-A36 Structural Steel

(Gupta & Khurmi, 2005)

Design of die for blanking operation

Blanking cuts the periphery of a stamped part in one operation. This operation is similar to perforating except the slug is saved as the finished product.

Strip layout

Figure 2 shows the strip layout. Economy Factor is depending upon the strip layout. From equation 5:

$$\textit{Economy factor } (E) \textit{ in}\% = \frac{(\text{Area of the blank } \times \text{number of raws } \times 100}{(\text{width of the strip } \times \text{Pitch}}$$

= 71.32%

Clearance

Die clearance is equal to the space between punch and die when the punch enters the die opening. (Mate, 2007)

$$\frac{t}{C_o} = 1.36\exp\ (\epsilon_r)\frac{2.3\exp\ (\epsilon_r) - 1}{2\exp\ (\epsilon_r) - 1}$$

C_o= 0.12mm

Diameter of punch (d_{p1})

$$\boldsymbol{d_{p1} = Blank\ diameter + m} \text{.................. } \mathbf{11}$$

= 136.55mm

Where m = elastic recovery

$$\boldsymbol{m = \frac{200 - E_f}{200} \times 100} \text{................................. } \mathbf{12}$$

E_f = the final elongation (TxDOT, 2014)

Diameter of the die (d_{d1})

$$\boldsymbol{d_{d1} = d_{p1} + Clearance} \text{............ } \mathbf{13}$$

= 136.67mm

Die Block Dimension

Perimeter (p_1) = $\pi \times d_{d1}$=429.36mm

$\boldsymbol{T_1} = 25.4 + (p_1)^{0.015} = 26.50mm$
$\boldsymbol{T} = T_1 + grinding\ allowance = 27mm$
$\boldsymbol{h} = 10\% \times T = 2.7mm$
$\boldsymbol{A} = 1.5 \times T = 40.5mm$
Angular clearance $\alpha = 2^0$ or 3^0
Recommended standard hardness for blanking dies and punches = R_c58- R_c63 (Stampingworld, nd)
Where,
T=Thickness of die block
h=Land of die block
A=Length of die block

Blanking force
From equation 7, $F_1 = \pi \times d_{d1} \times t \times \tau_s$
From table 1, $UTS = 400 \times 10^6 N/m^2 = 400N/mm^2$
But shear strength = 80% of UTS (Tool, nd)
Therefore, Shear strength $\tau_s = 320N/mm^2$
$F_1 = 16.5$ *tons.*

Stripping force
From equation 8, $F_2 = \frac{F_1}{10} = 1.65 tons$
Total force
From equation 9, $F = F_1 + F_2 = 18.15 tons$
Thickness of Plates
From equation 10, dies plate thickness
$DPT = \sqrt[3]{F}$
$= 56.6mm$
Top plate=1.5×DPT
$= 84.9mm$
Bottom plate=1.75×DTP
$= 99.1mm$
Punch holder plate=0.75×DPT
$= 42.45mm$
Stripper plate=0.5×TDP

=28.3mm

Design of die for punching operation

Punching operation (Ø13mm)

For this compound die, punching is the cutting operation by which Ø13mm hole is made at the centre of the blank.

Clearance = $\frac{t}{C_o} = 1.36exp\ (\epsilon_r)\frac{2.3exp\ (\epsilon_r)-1}{2exp\ (\epsilon_r)-1}$

C_o *= 0.12mm*

Diameter of punch *= 13.05mm*

Diameter of die *= 13.17mm*

Cutting force required

$F_c = \pi \times \text{diameter of punch} \times t \times \tau_s$

= 1.6tons

Die block dimensions

Perimeter (p_2) = *π × diameter of die = 41.37mm*

$T_2 = 25.4 + (p_2)^{0.015}$ *= 26.44mm*

$T = T_2 + grinding\ allowance$ *= 27mm*

h*=10%×T = 2.7mm*

A*=1.5×T=40.5mm*

Where,

P_2 = perimeter of die

T = thickness of die block

h = land of the die block

Angular clearance α = 2^0 or 3^0

Recommended standard hardness for blanking dies and punches = R_c58- R_c63 (Stampingworld, nd)

Punch design

Checking the punch for crushing,

$$\boldsymbol{Cutting\ force} = \frac{\pi}{4} \times d^2 \times \sigma_c \text{........................ } \mathbf{14}$$

15743.1=$\frac{\pi}{4} \times (13.05)^2 \times \sigma_c$

$\sigma_c = 117.6$ N/mm^2 << 750N/mm^2

Safe in crushing

Maximum length in punch

$$L_{max} = \frac{\pi \mathrm{d}}{8} \times \left(\frac{E \times d}{t \times \tau_s}\right)^{\frac{1}{2}}$$

L_{max} = 13.3mm

Taking total punch length to be 47mm

Press capacity

Press Tonnage = Blanking force + Punching force + Stripping force

= 16.5 + 1.65 + 1.6 = 19.75tons

Therefore, 20tons Press Capacity is suitable.

Working of compound die

Figure 5 shows the 3D views of the compound die; (A) is the upper half of the die assembly being turned upside down. (B) is the complete die assembly while (C) is the lower half of the compound die. The lower half is bolted on press table while the upper half fixed to the press spindle. The material strip is passed between the upper and lower assembly. When operated the press spindle descends down, the stripper presses the material on the die to keep it in position before the punch down for cutting operation.

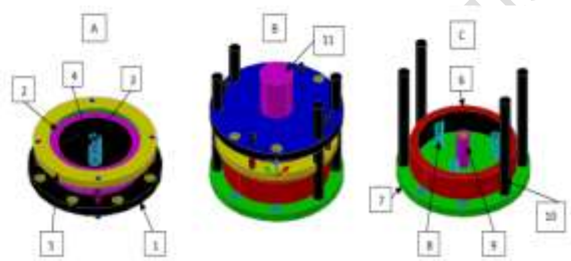


Figure 5: 3D Views of the Compound Die

A-Upper half (inverted), B-Complete assembly, C-Lower half assembly, 1-Punch plate, 2-Cutting punch I, 3-Cutting punch II, 4-Top ejection spring, 5-Stripping plate, 6-Blanking die, 7-Bottom plate, 8-Bottom ejection spring, 9-Punching die, 10-Guide post, 11-Shank.

Conclusion

It is possible to produce the product (drum plate) in a single die and stroke, which makes it possible to mass produce; thereby the unit cost will be low.

This is making it possible to fabricate portable agricultural machineries in mass, for small scale farmers. Because threshing drums and blowers as shown in Figure 4, are key components of most post harvest processing machineries.
Our unemployed youth can be engaged in fabrication of agricultural machineries locally, this will have a positive impact on our economy.

References

Bhaskar, F., & Mahesh, S. (2016). A Review on design, development, and analysis of compound die for Automobile component. *International Advanced Research Journal in Science, Engineering and Technology* , 121-123.

Black, J. (2004). *Workshop Processes, Practices and Materials* (Third ed.). Oxford: Linacre House, Jordan Hill.

Black, J. (2004). *Workshop Processes, Practices and Materials* (Third ed.). Oxford: Linacre House, Jordan Hill.

Bojanovic, V. (2004). *Sheet Metal Forming Process and Die Design.* New York: Industrial Press Inc.

Das, C. (nd). *Blanking Die and Piecing Die Design.* Retrieved october 29, 2016, from Blanking and Piercing Die Design - Scribd: https://www.scribd.com/doc/36668383/Blanking-and-Piercing-Die-Design

Ghosh, A., & Mallik, A. (1986). *Manufacturing Science.* New York: Ellis Horwoos Limited.

Gupta, R., & Khurmi, J. (2005). *Machine Design.* Ram Nagar, NewDelhi-110 055: Eurasia Publishing House (Pvt.) Ltd.

Krasugir. (2009, September 16). *Economy factor of strip layout.* Retrieved October 28, 2016, from Mechanical engineering: http://machining-technology.blogspot.com.ng/2009/09/economy-factor-of-strip-layout.html

Mate. (2007, December). *Die Clearance.* Retrieved November 8, 2016, from Mate Technical Data: http://www.abplanalp.com.ua/upload/files/MATE%20Technical%20Data.pdf

N/A. (2015). *Modulus of Elasticity or Young's Modulus - and Tensile Modulus for common Materials.* Retrieved October 9th, 2016, from The Engineering

ToolBox: http://www.engineeringtoolbox.com/young-modulus-d_417.html

NTTF. (2005, October 9). *Enhance your stuff* . Retrieved October 30, 2016, from http://enhanceyourstuff.blogspot.com.ng/2005/10/formulas-for-finding-out-die-plate.html

Parmindersigh, K., Chirag, H., Bharat, O., & Sana, H. (2014). Design and Manufacturing of Progressive Press Tool. *15th IRF International Conference*, (pp. 81-83). Chennai, India.

Sneha, S., & Dalu, R. (2012). Compound Die Design: A Case Study. *International Journal of Science and Reseach* , 389-392.

Stampingworld. (nd). *Recommended Standard Tool Steels and Hardness* . Retrieved November 9, 2016, from Techdata-Toolsteel hardness: http://stampingworld.com/technicaldatafiles/Techdata-Toolsteel%20hardness.pdf

Tool, W. (nd). *Tool Design.* Retrieved October 29, 2016, from Enhance your stuff: Formulas for finding out die plate thickne: http://www.wisetool.com/formular/formula.htm#1

TxDOT. (2014, October). *Measurement of Elastic Recovery of Tensile Deformation Using A Ductilometer.* Retrieved October 29, 2016, from Tex-539-C: http://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/500-C_series/pdfs/aph539.pdf