International Journal of Recent Engineering Research and Development (IJRERD)
Volume No. 02 – Issue No. 01, ISSN: 2455-8761
www.ijrerd.com, PP. 50-61

Design and Development of Compound Die for Bearing Cap

Mr. B. F. Satpute[1], M. S. Harne[2]

P.G.student of Mechanical Engineering, AVCOE, Sangamner, A.nagar[1]
Prof. Assistant Professor Mechanical Engineering, AVCOE, Sangamner, A.nagar[2]

Abstract: Press tool is one of the important method of converting raw material into finished product. Variety of products is manufactured by press working processes. While converting raw material to a finished product it is essential to have an accurate design of the product and also data required for manufacturing. Compound die is a press tool of collective operations performed on the sheet metal. The various operations are carried out in a single stroke. The design of compound die is largely depends on material of sheet metal, thickness of sheet metal and complexity of design and operations. This press tool has significance like high rate of production and minimum per unit cost of product. In present thesis the work is carried out to design the compound die which can perform two drawing and piercing operation simultaneously. Also intension is given on cost minimization of product with higher production rate.

Keywords: compound die, design complexity, simultaneous operation, press tool.

I. INTRODUCTION

A press is a machine tool used to cut metal by applying force. There are three different ways of working sheet metal in presses.

1. Shearing: In this operation metal is deformed to a shear failure in order to cut various contours from the metallic sheet.
2. Bending: It is a localized deformation within the plastic range.
3. Drawing: Drawing is a deformation that involving considerable change of shape.

Types of presses

1. Based on source of power
   a) Hand press
   b) Power press
2. Based on types of frame
   a) Pillar press
   b) Inclined
   c) Straight side press

The main parts of compound die are die and punch which are the actual operating members.

Die: A die as a complete tool consist of a pair or a combination of pairs of making parts or producing work in press. The main tool typically attached to the lower portion of the die set. The die contains a recess that provides space for the shaping or shearing of sheet metal.

Types of die

Dies are classified by type of operation performed and type of construction of die. The various types of dies are as:

1) Simple dies: These dies are designed to perform only one operation such as blanking, piercing, notching, trimming, drawing etc.

2) Multi-operation dies: These dies are designed to perform simultaneous operations in one stroke of ram.

These dies are further classified as follows:

a) Progressive die: In progressive dies the work piece moves from one station to another, and different operations being performed at each station. A die containing a series of stations that perform one press operation after another in series. A progressive die gradually forms a part as it moves through the die, and the last operation separates the part.

b) Compound die: In this dies two or more cutting operations such as blanking and piercing can be performed simultaneously in a single stroke at a single station. Compound dies ensure the positional relation between the various elements of work piece.

International Journal of Recent Engineering Research and Development (IJRERD)
Volume No. 02 – Issue No. 01, ISSN: 2455-8761
www.ijrerd.com, PP. 50-61

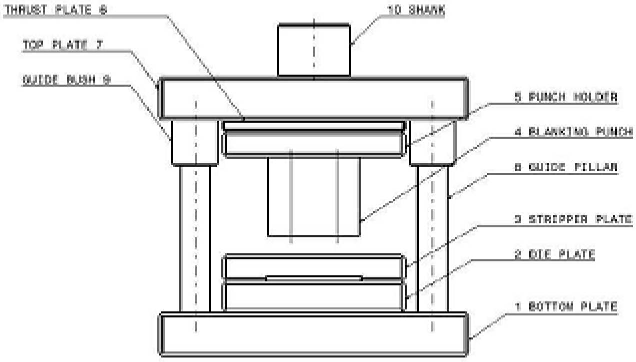

Fig. 1: Simple Press Tool [3]

Model of compound die shows the various parts. Lower shoe plate consists drawing punch. On its top portion it is having grooved which acts as piercing die. The upper shoe plate consists drawing die. It is having piercing punch at its end portion which activate at the end of drawing stroke. Both drawing and piercing operation is carried out simultaneously.

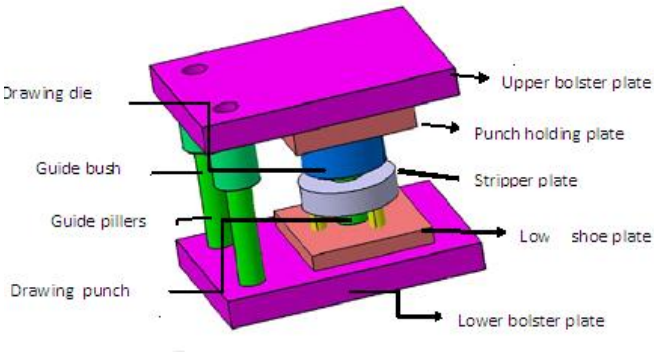

Fig.2: 3D model of compound die

II. LITERATURE REVIEW

B. Hogman has been presented, "Steel for Press tool**"** **(**2009) The ultra-high strength steel material is the best suitable as a press material due to its high tensile strength. The tensile strength of ultra-high strength steel can be up to 1400 MPa. Due to this very high strength the demand of automobile industry like weight reduction of material with increase in safety level can be fulfilled. In this paper the two steel sheet having grade Docol 800 DP and Docol 1400 DP having tensile strength 800 MPa and 1400 MPa resp. were investigated.The various parameters investigated are cutting clearance, burr height and type of wear with its distribution. The results for punch wear are plotted. He also analyzed the punch edge and surface condition after 140000 strokes. The appearance of cutting edge of material were also tested. Finally can conclude that the tool steel have good ductility, toughness and abrasive wear resistance.

Sutsan Thipprakmas, Wiriyakorn Phanitwong has been presented "Process parameters design of spring back and spring - go in V-bending process using using Taguchi method**"** (2011**)** In this paper the author represents the important parameter which influence on the spring back and spring go effect which largely depends on bending angle, punch radius and material thickness. He analyzed the v bending process by Taguchi method. In this paper the analysis of variance technique were carried out with respect to three process parameters with low level and high level. Validation through experimental method was carried out by AL material of 30 mm width and 3 mm thickness as working specimen. V bending die with 5-10 Ton capacity UTM was used for laboratory experiment. The punch radius taken as 2.5 mm, 3.5 mm, Material thickness as 2 mm, 3 mm and bending angle 30^0 , 45^0 as low and high levels of three process parameters. The results were analyzed for each process parameter with respect to both levels. The variation of mean stress with respect to material thickness was analyzed. Different pattern of stress distribution was plotted. It is conclude that the material thickness is the main factor for spring back and for spring forward the material thickness along with bending angle has the main contributor.

Vishwanath M.C. , Dr. Ramni , Sampat Kumar L. has been presentated **"**Design of progressive draw tool**"**(2013) In this paper the author uses the software like Pro/E to design the cup for oil filter by the progressive die technique. He design progressive die for two stage operation i.e. piercing and blanking. The principle of metal cutting through progressive die is explained along with its need to cator the optimization of resources and to get the advantage of this technique. The die designed for producing washer with its specifications like inner diameter, outer diameter and its thickness. He also describes the basic causes of shearing i.e. plastic deformation, penetration and fracture. Different force calculations for punching force and blank holding force was investigated. It was suggested that10% of actual force should considered as stripping force. He mentioned the required amount of clearance for shearing per side. And suggested that the essential amount of clearance should be of 1/4 th per side for better quality when material thickness is upto 1.5 mm. The different parts of die like die block, stripper plate, punch plate, stock guides, punches, top plates, bottom plates, guide pillars, side punches was designed using PRO/E software. Here we can conclude that accuracy of design is improved with reduction in process time for design by using this advanced software.

Mr. Amit D. Madake, Dr. Vinayak R. Naik,Mr. Swapnil S. Kulkarni have presentated "Development of sheet metal component with a forming dies using CAE software tool (Hyper form) for design validation and improvement**"**(2013) In this paper the author describe different aspects of sheet metal forming process. Forming process is the interaction between material properties, product specification and the forming process parameters (force, tooling and lubrication). In forming process the major problem is due to bad control of holding, restraining and spring back effect which causes the different geometrical defects like wrinkling, necking, drawing grooves and fractures. The work is focused to minimize the defects evident during the phase of development. He perform the design calculations for designing Cup which is the part of two wheeler mounting bracket and found out the blank diameter as per specifications provided. Draw ratio is considered as 0.31 (H/D) for easy draw. He investigate the required dimension of die block, top plate, bottom plate, punch height, Draw and punch radius, blank holding force (30% of draw force) and press capacity to perform the operations. The modelling of component is done by using CAD software (unigraphics NX-6) and analysed the component by using simulation software HYPERFORM and results are plotted for analysis of blank holding force at 5 Tone and 10 Tone. Thus the analysis is carried out by changing the operating conditions like blank holding force and results were analysed. The results obtained established the guideline for forming die design for drawing materials.

Kailash kumar Lahadotiya, Abhay Dinkar Kakirde and Ashutosh Kumar Pandey have presentated "Mini review on designing of press tool for sheet metal component**"** (2013) In this paper the author mainly focus on economic consideration of the part (die) development. The selected material for die should be optimized with respect to tool life, higher productivity with reduced cost. He suggest the general cost distribution which include die material cost (20%), machining of component cost (65%), heat treatment cost (5%), and assembly & adjustment cost (10%) He also express the different factors which influence the life of tool component (due to material composition, material properties), design of component (component dimension and complexity), maintenance of component. (Regrinding, polishing, cleaning, stress tempering etc.) Thus in this paper the work is carried out with respect to economical expenditure and important factors in design process.

III. GAP IDENTIFICATION & PROBLEM DEFINATION

Gap Identification: - Mostly the number of press operations are performed by using simple dies individually even it consists very simple operations. That directly affects on rate of production and hence all the expenses were increased which increased per unit cost of product. If we convert these simple dies into compound die by considering design complexity, we can cater most of advantages by using compound die.

Problem Definition: - The task of project is to modify the die used for the production of bearing cap used in rock crushing machine. This bearing cap was initially produced using simple dies which perform the various operations Separately that requires number of dies. This took a lot amount of time for the production of each product, thereby increasing the cost, production time and energy supplied for the production of each component/part. This problem may be compensated by using compound die in which two drawing operations and piercing operation will be performed simultaneously

IV. OBJECTIVES & METHODOLOGY

Objectives:-

1. To understand the methodology of die design.
2. Reduce tooling and its maintenance cost.
. 3. Per unit cost minimization of product.

Methodology:-

1. Selection of optimized material for die and punch.
2. Design and optimization of Punch and Die.
3. Assembly of Dies and Punch on 3D software
4. Verification of Outcomes.

Product Description:-

Name of the component: Bearing cap
Material: Mild steel
Thickness: 2.8 mm
Shear Strength: 400 MPa

Fig. 3 Final component

Table 1. Chemical Composition of D2 Material [8]

Chemical composition	**C**	**SI**	**Cr**	**MO**	**V**
Percentage	**1.5**	**0.30**	**12.00**	**0.80**	**0.90**

Properties of D2 Material:
Elastic Modulus = 210000 N/mm^2
Poisons Ratio = 0.3
Shear Modulus = 7900 N/mm^2
Mass Density = 7700 Kg/ m^3
Tensile Strength = 1736 N/mm^2
Compressive Strength = 2150 N/mm^2
Yield Strength = 1532 N/mm^2

V. DIE DESIGN CALCULATIONS

1. Force calculation:

a) Shear Force for piercing:

Shear Force = Perimeter x T x τs [4]
= π x 21 x 2.8 x 400
= 73890 N

T = Thickness in mm
τs = Shear Strength in N/mm^2

b) Force for drawing operation:

Drawing force = $\pi \times d \times t \times$ Yield strength $\times$ (D/d - c) [1]
= $\pi \times 50.1 \times 2.8 \times 520 \times (103/50.1 - 0.6)$
= 333639.1504 N

d = dia. of shell
D = dia. of blank
C = clearance generally taken as 0.6 to 0.7

Force = Piercing force + drawing force
= 73890.0+333639.1504

= 407529.150 N

Stripping force is considered as 10% of total force [11]

= 10/100 × 407529.150

= 40752.915

Total force = Piercing force + drawing force + stripping force

= 73890.0+333639.1504+40752.915

= 448282.065 N

= 448282.065/9810

= 45.6964 Tones

By considering 70% press efficiency [8]

= 45.6964 /0.7

= 65.28 Tones

Press Tonnage = 65.28Tones

2. Punch and die dimensions:

Punch size = Diameter of piercing hole

= 21 mm

Piercing punch height = 60 to 80 mm standard taken for future expansions.

Die size = Punch size+2×clearance (3% to 5% of material thickness) [10]

= 21+ 2× 4/100 ×2.8

= 21.224 mm

Die height = twice of material thickness

= 2× 2.8

= 5.6 mm

Punch size = Diameter of shell

= 44.5mm

Die size = Punch size + thickness of material + 2 × clearance (2.5% of material thickness)

= 44.5+ (2.8 × 2) +2× (2.5/100 ×2.8)

= 50.1+0.07

= 50.17 mm

b) Drawing punch and die dimensions:

Drawing punch size = Internal diameter of shell

= 44.5 mm

Drawing punch height = 21.5 mm

Consider punch height = 26.5mm

Drawing die dimensions

Diameter of die = 44.5 +2 (2.8) + 2 × clearance

Clearance = 0.125 of thickness

= 0.125×2.8 × 2

= 0.7 mm

Diameter of die = 44.5+ (2×2.8) + 0.7

= 50.17 mm

Drawing die height =21.5 mm

VI. PUNCH & DIE ANALYSIS

After designing and modelling the press tool is analyzed by using ANSYS software to ensure the correctness of design. The analysis part is very essential to avoid the damage of meeting parts because for press tool very costlier material like D2 and OHNS (oil hardened non shrinking steel) are used. To prevent this material from damage, analysis must be carried out. Also due to analysis the designer comes to know the distribution of stresses and deflection of the punch for particular operation. It provides an opportunity to improve the design of the part before manufacturing.

a) Piercing punch analysis:

After modeling of piercing punch it is analyzed by using software. For analysis we have to feed the specification like dimensions, applied force and material properties like modulus of elasticity, shear modulus, Poissions ratio, mass density and strength of material. The stress distribution and displacement of punch under the applied loading condition is as shown.

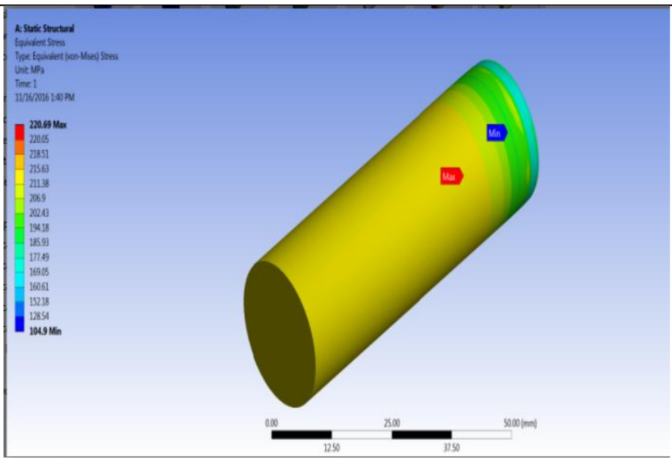

Fig.4: piercing punch stress distribution

Table No.2: Stress Distribution in Piercing Punch

Component Particulars	Analytical Results	FEM Results	
	Max. value	Min. value	Max. value
Piercing Punch	213.33 N/mm^2	104.9 N/mm^2	220.69 N/mm^2

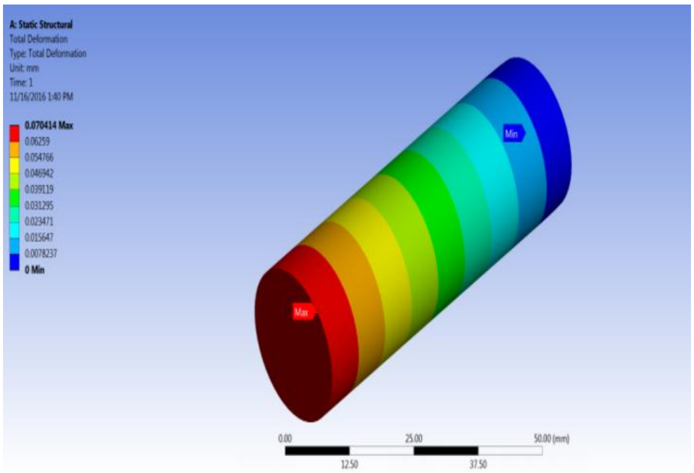

Fig. 5: piercing punch deformation

Table No.3: Deformation in Piercing Punch

Component Particulars	Analytical Results	FEM Results	
	Max. value	Min . value	Max. value
Piercing Punch	0.0711 mm	0.00 mm	0.0704 mm

b) Drawing Punch analysis:

After modelling of drawing punch it is analysed by using ANSYS software. After applying force intensity and material properties like modulus of elasticity, shear modulus, Poissions ratio, mass density and strength of material the analysis is carried out. The below figure shows the stress distribution zones indicating different stress intensity and minimum to maximum deflection areas.

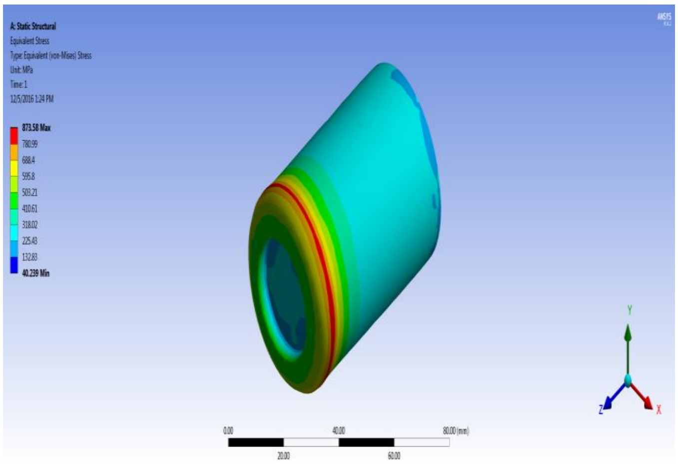

Fig.6: drawing punch stress distribution

Table No.4: Stress Distribution in Drawing Punch

Component Particulars	**Analytical Results**	**FEM Results**	
	Max. value	**Min. value**	**Max. value**
Drawing punch	852.332 N/mm^2	873.58 N/mm^2	40.23 N/mm^2

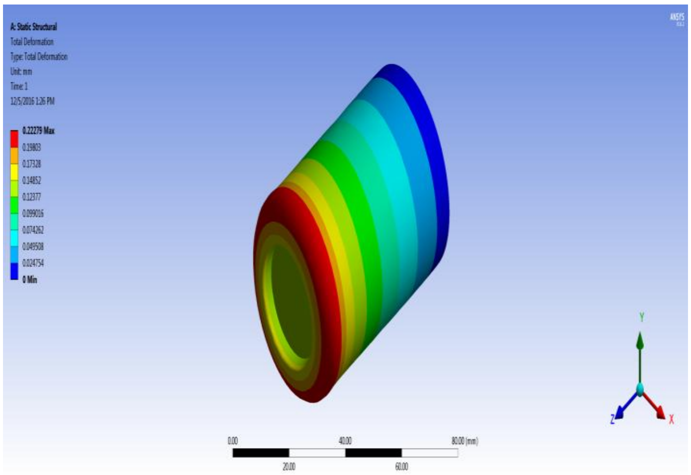

Fig.7: drawing punch deformation

Table No.5: Deformation in Drawing Punch

Component Particulars	**Analytical Results**	**FEM Results**	
	Max. value	**Min. value**	**Max. value**
Drawing punch	0.2638 mm	0.00 mm	0.2227 mm

VII. TIME STUDY

Time study is one of the important phenomenon after converting the existing dies into compound die in which three operations are performed by a single die. By measuring the actual time required for manufacturing of product with existing and compound die method. I get the information like actual machining time saving and material handling time saving. In press operations lot of time is consumed in material handling on the other hand the machining time is very less if we compare it with the material handling time. As the material handling time is more the idle time of machine is also increased which affects on the cycle time of manufacturing single product and hence the overall rate of production.

Table No.6: Time Study for Existing Die

Sr. No	Stages	Operation	Time (Sec)	Quantity /hour
1	First Stage	First draw	5	133
		Material handling after first draw	7	
2	Second stage	Second draw	5	
		Material handling after second draw	7	
3	Third Stage	Piercing	3	

Table No.6: Time Study for compound Die

Sr. No	Operation	Time (Sec)	Quantity /Hour
1	Combine operation (Piercing and Drawing)	6	257
	Material handling after completion of stroke	8	

Calculation for time study

Time required producing one component in existing method

= 5+7+5+7+3= 27 sec/component

X = 133component/hour

Time required for producing one component in compound die method = 8+6 = 14 sec/component

Y = 257component / hour

% increase in production = ((Y-X)/Y) ×100

= ((257-133)/257) ×100 = 48.25%

Increase in production rate due to compound die is 48.25%

VIII COST ESTIMATION

A) Tooling cost:

In press manufacturing process tooling cost is an important aspect. Major part of costing is belongs to expenditure spent on tools. Tooling cost is the cost associated with the raw material required for manufacturing of tool, cost of selected parts like guide pillar and guide bush, cost of converting raw material into tools. Press tool requires hard and expensive material like oil hardened non shrinkage steel and high carbon high chromium steel which requires higher cost. As this material is to be machined with close tolerance, it requires modern and special purpose machines. This increases the cost of tooling. Due to involvement of compound die in press machining its cost can be controlled up to some limit. Here the intension is given to reduce the cost of tooling.

International Journal of Recent Engineering Research and Development (IJRERD)
Volume No. 02 – Issue No. 01, ISSN: 2455-8761
www.ijrerd.com, PP. 50-61

Table No.7: Cost Estimation

Sr.No	**Description**	**For existing method**		**For compound die method**	
		Weight	Total cost	Weight	Total cost
1	Mild Steel plate for top and bottom Bolster plate Rate of each Kg Rs 65/- per Kg	110Kg	4620/-	110Kg	4620/-
2	High Carbon High Chromium steel material for Punch and Die (Rs 220/-Kg)	60 Kg	13200/-	30 Kg	6600/-
3	Guide pillar made up of high carbon steel (Rs 1500 per pillar)	6 pillars reqd	9000/-	2 pillars reqd	3000/-
4	Fastener required(Rs 80/-Kg)	5 Kg	400/-	2 Kg	160/-
5	Manufacturing cost for die and punch	-	12430/-	-	8650/-
6	Additional Charges on die (50%of manufacturing cost)	-	6215/-	-	4325/-
	Total cost required for manufacturing of dies	**-**	**45865/-**	**-**	**27355/-**

Percentage cost reduction is given by

Difference in cost with two methods / cost of existing method

= (45865-27355)/ 45865 = 18510 / 45865

= 0.4035 = 40.35%

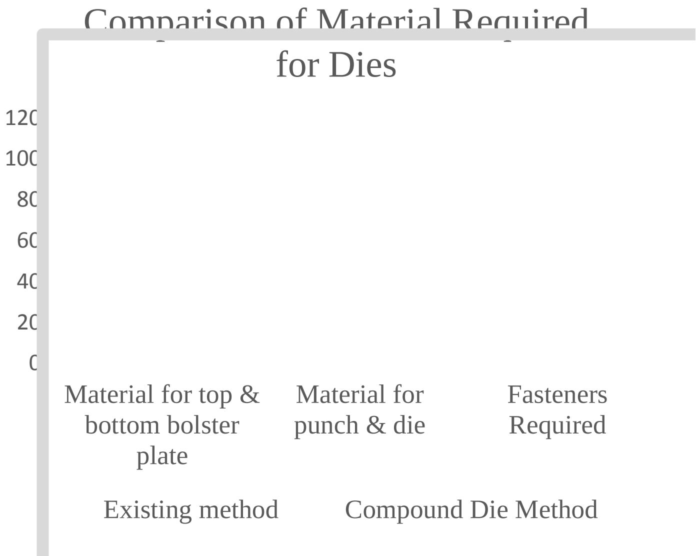

Fig. 8 Material Required for Dies

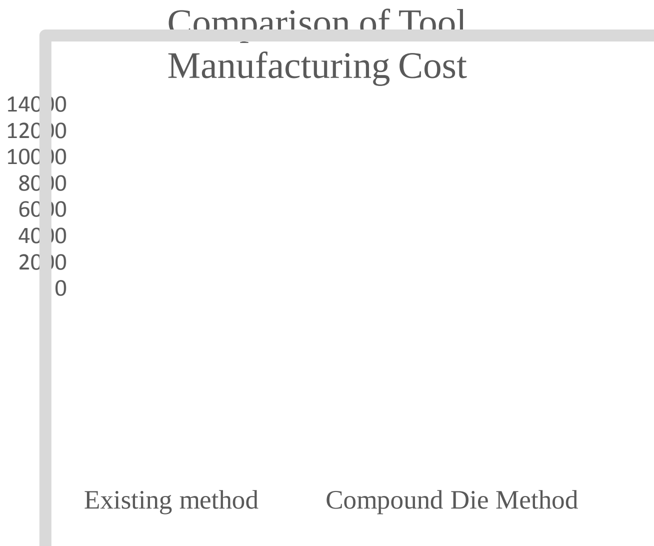

Fig. 9 Tool manufacturing Cost

Remark:

From the comparison of cost required for manufacturing of existing dies and compound die it clearly shows that for manufacturing of compound die less material is required. The above two table shows the costing required for manufacturing of existing three dies and compound die. The figure shows the actual cost of manufacturing the dies. It shows the percentage cost reduction by 40.35%

B) Per unit cost of product:

This unit cost of component includes different cost factors like raw material cost, actual cost of press manufacturing, maintenance cost and labour cost. The different costs associated with the component are as follows.

Raw material cost:

Sheet metal strip size = strip length × strip width × sheet thickness
= 1250 × 118.90 × 2.8
= 416150 mm^3

Raw material required for single component = strip size / No. of component in each strip
= 416150 / 11
= 3.7832×10^{-5} m^3

Weight of raw material for single product = material volume × density
= $3.7832 \times 10^{-5} \times 7850$
= 0.29698 Kg

Cost of raw material for each component = material weight × cost per Kg.
= 0.29698 × 65
= 19.30 /-

1) Cost of product manufacturing with existing dies:

a) Maintenance cost = = 0.50 (for five dies)
After each 5000 units maintenance of each die is required

b) Shearing machine cost =1.50 per Kg (0.20/- per piece)
Blanking = 0.80/- per piece
First draw operation = 0.90/- per piece
Second draw operation = 1.10/- per piece
Punching = 0.50/- per piece

c) Labour cost = 500/- per 3000 Nos. (4 operation) i.e. (0.60×5 =3.00/- per piece)

Per unit cost = (material cost + manufacturing cost + maintenance cost+ Labour cost)
=19.30 +(0.20+0.80+0.90+1.10+0.50+0.50+3.00)
= 26.30/-

2) Cost of product manufacturing with compound die:

a) Manufacturing cost:

Shearing machine cost =1.50 per Kg (0.20/- per piece)
Blanking = 0.80/- per piece
Compound die operation = 1.30/- per piece
b) Labour cost = 500/- per 3000 Nos. (3 operation) (0.60×3 =1.80/- per piece)
c) Maintenance cost = (0.30/- for three dies)
After each 5000 units maintenance of each die is required (500)
Per unit cost = material cost + manufacturing cost + maintenance cost +Labour cost
= 19.30+ (0.20+0.80+1.30+0.30+1.80)
= 23.70 /-
Reduction in per unit cost = 2.6/26.30 = 9.8%

Table No.8 Cost Estimation for unit component

Sr. No.	Particulars	Cost by existing method	Cost by Compound Die method
1	Machining cost	3.5	2.3
2	Labour cost	3	1.8
3	Maintenance cost	0.5	0.3

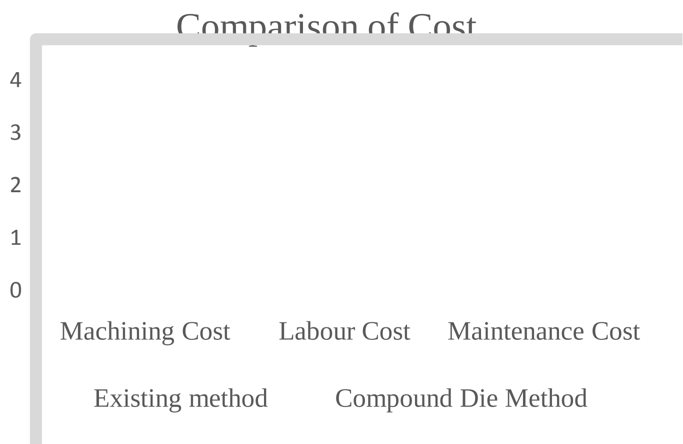

Fig.10 Cost Comparison for Single Component

Remark:

The above calculation shows the actual cost of component with the existing die method and compound die method. By the use of compound die there is reduction in maintenance cost, manufacturing cost and labour cost. Hence the cost of unit component is reduced by 9.8%.

IX. CONCLUSION

The compound die is designed for existing operation instead of simple die. The analytical and FEM results for piercing and drawing (punch, die) are quite differ from each other but that are in permissible range. The tooling cost is reduced by 40.35% as there is considerable saving in the raw material required for making of compound die and hence in manufacturing of compound die instead of existing dies. Due to contribution of compound die the rate of production is increased by 48% which directly affects on per unit cost of product.The unit cost of product is reduced by 9.8% due to compound die because there is reduction in cycle time of operation along with material handling time.

ACKNOWLEDGMENT

I express my sincere and gratitude to Prof. A. K. Mishra (H.O.D.), Prof. V. S. Aher (P. G. Co-ordinator) and Prof. M. S. Harne (Guide) for their time to time suggestions and guidelines, for their indispensable help.

REFERENCES

[1]. "Development of a Sheet-Metal Component with a Forming Die Using CAE Software Tools (Hyper form) For Design Validation and Improvement" by Amit D. Madake International Journal of Modern Engineering Research (IJMER) (2013)
[2]. "Process parameter design of spring-back and spring-go in V-bending process using Taguchi technique" by Sutasn Thipprakmas Wiriyakorn Phanitwong Materials and Design (2011)
[3]. "Mini Review on Designing of Press Tools for Sheet Metal Parts" by Kailash Kumar Lahadotiya, Abhay Dinkar Kakirde and Asutosh Kumar Pandey (2013)
[4]. "Design of progressive Draw Tool" by VishwanathM.C, Dr. Ramni, Sampath Kumar L. (2013)
[5]. "Steel for Press Tools" by B Hogman (2009)
[6]. "Causes & Preventation of Defects (Burr) In Sheet Metal Component" by Pawan Kumar Rai, Dr. Das Mohammad, HasanZakir Jafri,(2008)
[7]. "Experimental determination of spring back and thinning effect of aluminum sheet metal during L-bending operation" by K. Dilip Kumar, K.K. Appukuttan, V.L. Neelakantha, Padmayya S. Naik
[8]. "Design and Analysis of Blanking and BendingPress Tool to Produce Anchor Bracket Component" by Anudeep S,N. Ramesha
[9]. "Compound Die Design: A Case Study" by Sneha S. Pawar, R. S. Dalu
[10]. "Design of Combined Press Tool for the Manufacturing of Rice Thresher Blade" by Fissha Biruke Teshome, Yonas Mitiku Degu.
[11]. "Progressive tool design and analysis for 49 lever 5 stage tool" by H. Amresh, Hari Shankar.