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# Experimental Study on Removing Wrinkle Defect

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***Abstract:** Manufacturing is the process of turning raw materials or parts into finished goods through the use of tools, human labor, machinery, and chemical processing. In Aerospace industry, the most commonly used manufacturing process is sheet metal forming processes that helps in manufacturing the parts for tons of known and unknown purposes. Sheet metal forming process is done on a press and the parts are formed in between two die. It involves reshaping a metal while it is still in its solid state. Example of sheet metal forming process are bending, stretch forming, deep drawing, etc. But in aerospace industry, their exists some parts which occurs wrinkling defect while forming process, which is because of uncontrolled material flow into the die radius and no holding for the blank during forming , needs to be rectified. It is one of the major defects in sheet metal forming processes. It may become a serious obstacle to implementing the forming process and assembling the parts, and severe wrinkling may leads to break the part.*

***Keywords:** Blank holder, draw bead, wrinkle defect, forming process, sheet metal,*

## I. INTRODUCTION

Sheet metal parts have been applied in various industrial sectors such as automobile, aerospace, and electrical equipment. In sheet metal forming usually a metal blank is plastically deformed into a useful part with a complex geometry. Bending, flanging, deep drawing, and stretch forming are examples of sheet metal forming processes. The overall objective is to form the part without any defects and within the required tolerances. Sheet metal forming process is a system and several parameters affect the final result. Wrinkling, which is formed by excessive compressive stresses, is one of the main failure modes and may lead to assembly problems in sheet metal forming process. There are many factors affecting wrinkling such as the mechanical properties of sheet material, geometry of the sheet and tooling, process parameters, and contact conditions. The control of wrinkling is difficult due to the complex deformation behavior of the sheet metal. Wrinkling is one of the key research problems in the sheet metal forming field. Deep drawing is a major sheet metal forming process. In this process, a mechanically applied force forms a flat sheet of material to a desired shape. In deep-drawing, wrinkling and cracks have to be avoided by control of material flow. Wrinkling is usually undesired in final sheet metal parts for functional and aesthetic reasons. It is unacceptable in the outer skin panels where the final part appearance is crucial. The quality of sheet metal component depends on the rate of flow of blank into the die cavity. By controlling the material flow rate, we can prevent the defects such as wrinkling. In deep drawing and stretch forming operations, generally the restraining force required to control the material flow is provided by either the blank holder or the draw beads. As a result, the tensile stresses are increased, material flow is controlled, and the formation of wrinkles is avoided. The restraining force is provided by the blank holder or draw bead to control the material flow rate and the force is created by friction between the blank & tooling. Blank holder, draw beads, type and amount of lubricant as well as shape and size of initial blank represent possibilities to influence material flow. The sheet metal is subjected to bending and unbending around the draw bead after the die closure. To produce an optimal part with the minimum use of material, the position, height & strength of draw bead can be modified. One of the most important parameters affecting the quality of the final part is lubrication conditions between the sheet and tool surfaces. By controlling the lubrication condition defects such as wrinkling, tearing, and tool wear can be reduced, in metal forming, especially in the deep drawing process, lubricants are used to reduce the friction between tool and work piece.

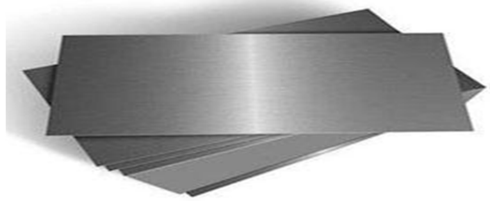

Fig. 1. Sheet Metal Blank

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## II. SUMMARY OF PART

LENGTH = 600 mm
WIDTH = 300 mm
THICKNESS = 1 mm

The name of the part is A4RMBLICH.The part is of the Section [19.1] .The part is of AIRBUS 320 family. It is the TAIL PART. The part is made up of Aluminum. The shape of the part is like a half moon. The parts has high rejection rate.

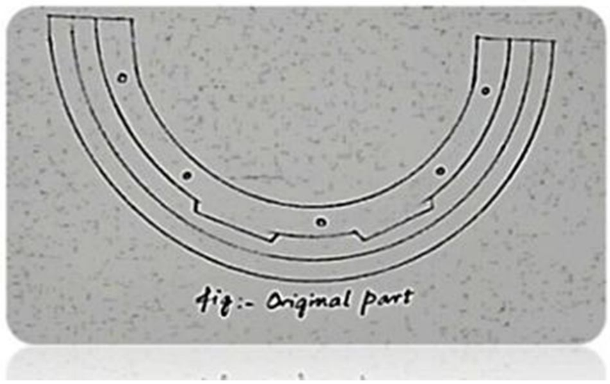


Fig. 2. Part sketch

## III. METHODOLOGY

### A. *Problem Identification*

Generation of wrinkles during forming at flange area of part. High rejection rate because of wrinkles. Wrinkle - One of the primary defects that occurs in deep drawing operations is the wrinkling of sheet metal material, generally in the wall or flange of the part. The flange of the blank undergoes radial drawing stress and tangential compressive stress during the forming process.

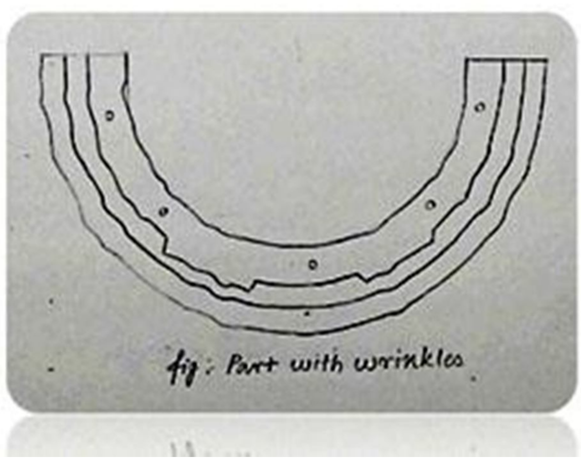


Fig. 3. Part with wrinkle sketch

### B. *Observation Table*

Table 1. Rejection rate of part with old tool

| Sr. No. | Month | Part form | Part with wrinkle | Rejection rate % |
|---|---|---|---|---|
| 1 | October | 100 | 52 | 52 |
| 2 | November | 100 | 50 | 50 |
| 3 | December | 100 | 51 | 51 |
| 4 | January | 100 | 50 | 50 |

## IV. LITERATURE REVIEW

“Naryansamy & Sowerby, stated that Wrinkling in sheet metal forming, with tearing, is one of the most important instabilities that occur in parts formed using stamp forming and deep drawing processes. This phenomenon limits the type of parts and geometries that can be formed using these techniques. An accurate model that could accurately predict the formation of wrinkling could also be used at the tooling design stage of parts of various shapes. ”

“Gasper Gantar , focused on the issues related to sheet metal forming such as determination of optimal product shape and optimal initial blank geometry, prediction of fracture, prediction of final sheet thickness, prediction of wrinkling, prediction of loads acting on the active tool surfaces, prediction of spring back and residual stresses in the product. The finite element method using numerical simulation was used to develop the process for the manufacture of defected less part. He used industrial examples for the research.

“A. V. Desai , optimized the draw bead location and thickness and strain variations were analyzed using finite element method for the panel header drawing blank holder to reduce the thinning effect of blank caused due to the forming process. ”

“Sandeep Patil, studied the effect of blank holding force and friction force on steel sheet of 1 mm thickness and their effect on wrinkles and wall thickness distribution is analyzed by using Hyper Form software ,their analysis reveals that as the blank holding force increases from 2 KN to 20KN no. of wrinkles form on flange reduced, experimentation is done by using various values and from that it is conclude that friction coefficient have great influences on thickness distribution in deep drawing. ”

“S. Yossifon and j. Tirosh, published a series of articles dealing with simple analysis of the deep drawing process as applied to the formation of cups from metallic materials such as copper, aluminum, steel and stainless steel and “Surya Kumar” published investigation and analysis for the wrinkling behavior of deep drawn die sheet metal component.

“S. Raju, G. Ganesan, R. Karthikeyan, reported that Deep drawing is one of the most important processes for forming sheet metal parts. It is widely used for mass production of cup shapes in automobile, aerospace, Railways and packaging industries. Drawing, also its importance as forming process, also serves as a basic test for the sheet metal formability. The effect of equipment and tooling parameters results in complex deformation mechanism.

“Lo, Hsu and Wilson, expanded upon the earlier work of Yossifon and Tirosh by applying the deep drawing hydro forming theory to the analysis of the hemispherical punch hydro forming process. The purpose of this work was to determine a theoretical method of predicting failure due to wrinkling. ”

“Chandra Pal Singh, studied the deep drawing process parameters like as blank-holder pressure, punch radius, and die radius, material properties, and coefficient of friction to manufacture the part with a minimum defect. ”

### *A. Problem Solution*

#### *1) Addition of Blank Holder*

Our main aim is to control the flow of material. We have to develop the area where material is going to hold. It is possible by Blank Holding Concept .Blank holder is used to hold the part of material. The function of which is to facilitate controlled material flow into the die radius.

A constant pressure is applied throughout the entire drawing section when a blank holder is used. Used of Lubricant for slippery moment action. Lubricant are used to flow the material in the rough areas. Lubricants reduce the friction between the blank and the punch and die cavity and can be liquid (wet) or films (dry). Generally, they are applied to the blank before drawing.

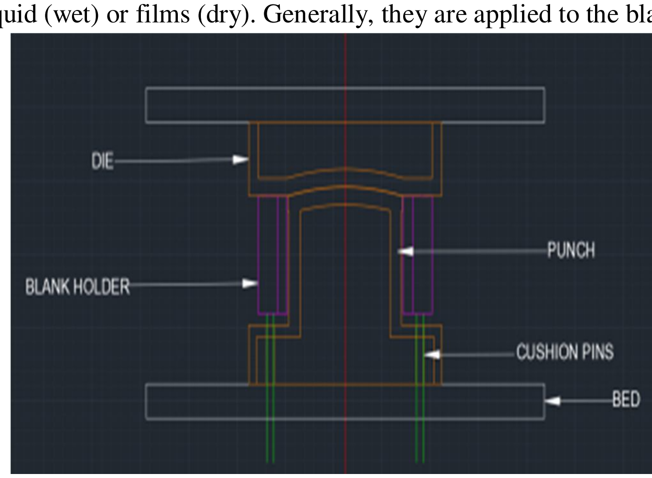


Fig. 4. Conceptual drawing of blank holder

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*2) Addition of Draw Bead*

We need to form the part in the control way. Because of the blank holder and lubricant, the material comes up immediately .To restrict the flow of material, I add draw bead over the blank holder. It restrict the flow of material

Draw bead control material flow during the drawing operation in order to achieve the optimal forming of a part without wrinkles. The material which are given to the part should be accurate that the parts form in given material which is possible by beads mounted on the on the blank holder. Beads work like a speed breaker

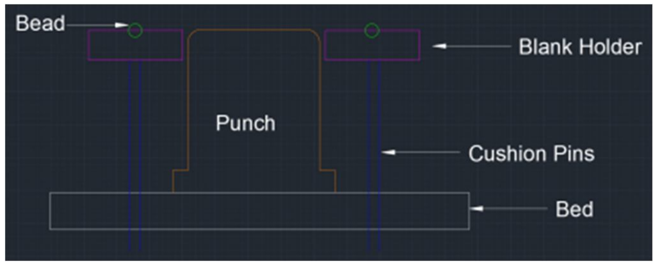


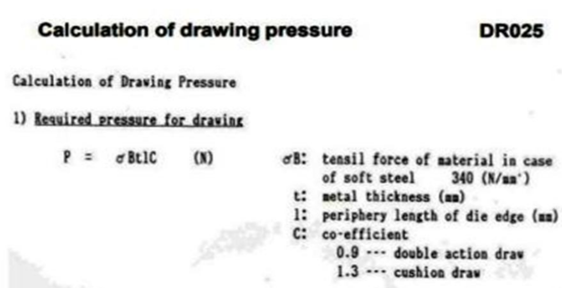

Fig. 5. Conceptual drawing of draw bead

## V. DESIGN CALCULATION

FOR DESIGN, I FOLLOWED TATA TOOL DESIGN STNADRAD AND STANDRAD DESIGN TOOL GUIDELINES.

### *A. Draw Force or Forming Pressure [P]*

The Part = 600 mm x 300 mm
Tool = 1000 mm x 1000 mm
Sheet thickness or metal thickness (t) = 1 mm
Periphery of circle (l) = 2πR
= 2 x 3.14 x 600
= 3768
≈ 3770 mm
Co-efficient or Safety factor (C) = 1.3
Material of Part = 2000 series Aluminium Alloy
Aluminium alloy 2024, where Copper is alloying element.
Temper of the material= 2024-T3
Ultimate tensile strength of material (σB) is 415 MPa..



**Calculation of drawing pressure** **DR025**

Calculation of Drawing Pressure

1) Required pressure for drawing

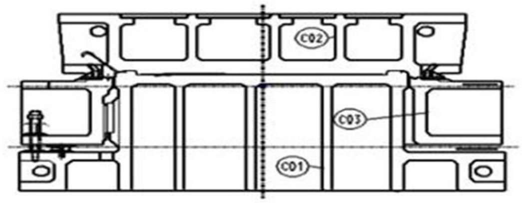
P = σBtlC (N)

σB: tensil force of material in case of soft steel 340 (N/mm²)
t: metal thickness (mm)
l: periphery length of die edge (mm)
C: co-efficient
0.9 --- double action draw
1.3 --- cushion draw

Fig. 5. Tata tool design standard for finding pressure

We have,
Draw Force or forming pressure (P)
= Periphery of circle (l) x Metal thickness (t) x Co-efficient (c) Ultimate tensile strength of material (σB)
= 3770 x 1 x 1.3 x 415
= 20, 33,915 N
= 203 Ton

*B. Casting Material Selection*

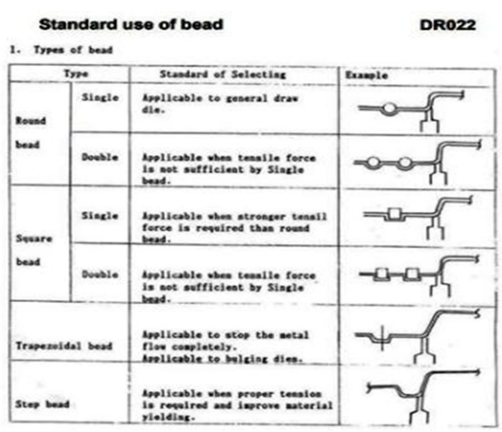



| IT.NO. | DESCRIPTION | MATERIAL | HEAT TREATMENT |
|---|---|---|---|
| C01 | LOWER CASTING WITH INTEGRAL PUNCH | FG300 MnCr/RFO | F'HRD 50-55 HRC |
| C01 | LOWER CASTING WITHOUT INTEGRAL PUNCH | FG300/RFO | — |
| C02 | UPPER CASTING | FG300 CrMo/RFO | F'HRD 50-55 HRC |
| C03 | BLANK HOLDER | FG300 CrMo/RFO | F'HRD 50-55 HRC |

Fig. 6. Tata tool design standard for casting material

Material should tolerate the impact force . Material should have high strength.
Material should be easily machinable.
For that We used Casting Material
For lower casting,
FG-300 Mn Cr
Chromium
Manganese
Tensile strength
Flake Graphite
Has hardness of 50-55 HRC (Rockwell c hardness usually for hard cast iron)
For Upper casting and blank holder
We used,
FG-300 Cr Mo
Molybdenum
Chromium
Tensile strength
Flake Graphite
It is cheaper than the other materials. It has a cost of 80 Rs/kg in Market. While casting, there is occurrence of porosity, blow hole, casting can be failed. To remove this, we followed basic guidelines of casting. Right material to address the impact force

*C. Selection of Draw Bead*


**Standard use of bead** DR022

1. Types of bead

| Type | | Standard of Selecting | Example |
|---|---|---|---|
| Round bead | Single | Applicable to general draw die. | |
| | Double | Applicable when tensile force is not sufficient by Single bead. | |
| Square bead | Single | Applicable when stronger tensil force is required than round bead. | |
| | Double | Applicable when tensile force is not sufficient by Single bead. | |
| Trapezoidal bead | | Applicable to stop the metal flow completely. Applicable to bulging dies. | |
| Step bead | | Applicable when proper tension is required and improve material yielding. | |

Fig. 7. Tata tool design standard for selection of bead and standard use of bead

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We selected round bead of single type as it applicable to general draw die.

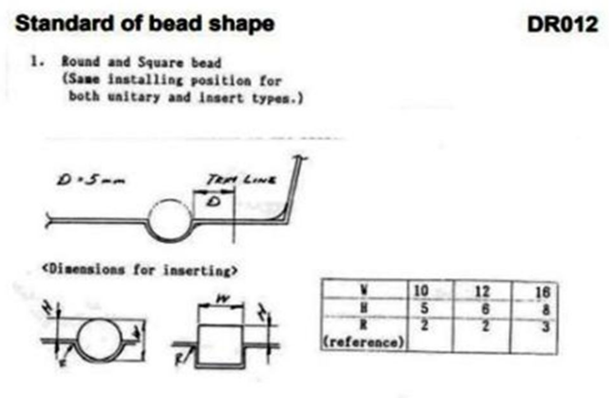
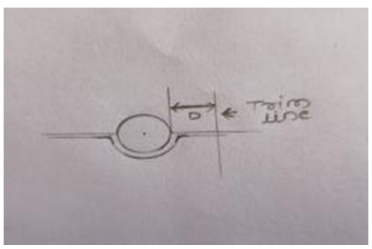
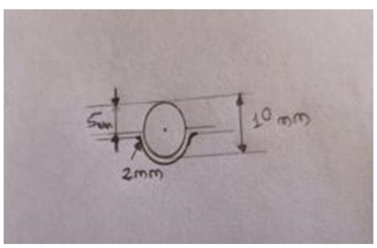



Fig. 8. Tata tool design standard for selection of bead shape




From the standard Trim Line D = 5 mm.




From the standard
W =10 mm
H = 5mm
R = 2mm

*D. Die Height*

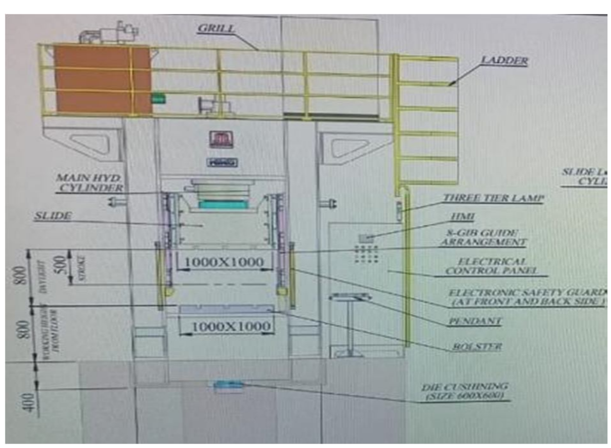



Fig. 9. Tata tool design standard for die height

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DAYLIGHT = is the maximum opening on a hydraulic press measured between the slide and bolster surface = 800 mm.
STROKE =the total distance the ram can travel from full extension to full retraction = 500 mm.
DIE HEIGHT
= DAYLIGHT - STROKE
= 800 - 500
= 300

### *E. Weight of Tool*

Length = 1000 mm
Width = 1000 mm
Height = 600 mm
∴ We have,
VOLUME = length x width x height
= 1000 x 1000 x 600
= 60, 00, 00,000 mm3
Density of cast iron = 7300 kg/m3 = 0.0000073 kg/mm3
Now,
WEIGTH = volume x density
= 60, 00, 00,000 x 0.0000073
= 4380 kg
Solid Weight of tool = 4380 kg
We used Casting tool.
So, we need to reduce the weight by minimum 30% because of weight reduction core.
∴ Weight of tool = Reduced 30% from solid weight of tool
= 3066 kg

### *F. Design for Lifting eye Bolt*

**Standard of tap for lifting**

* Taps for lifting should be provided on four(4) places of large part considering its balance.
1 - 4 taps are required for small part also.

Tap for lifting: (during eye bolt use)

| | Steel, Casted iron | | Non-Ferrous Metals | |
|---|---|---|---|---|
| d | one on vertical | two on 45° | one on vertical | two on 45° |
| M12 | 220 kg | 220 kg | - 140 kg | 140 kg |
| 16 | 400 kg | 400 kg | 270 kg | 270 kg |
| 20 | 600 kg | 600 kg | 400 kg | 400 kg |
| 24 | 1,000 kg | 1,000 kg | 670 kg | 670 kg |
| 30 | 1,700 kg | 1,700 kg | 1,100 kg | 1,100 kg |
| 36 | 2,300 kg | 2,300 kg | 1,500 kg | 1,500 kg |

Fig. 10. Tata tool design standard for lifting eye bolt

Weight of tool = 3066 kg
Taps for lifting should provide on four places of large part considering its balance.
∴ we consider 4 taps
As we consider 4 taps, weight equally divided into 4 lifting pin
= 3066 ÷4
= 766.5 kg
As weight occur above 600 & below 1000 Kg
∴ Diameter of eye bolt = 24 mm

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### G. Die Guide Design

**Standard of die guide designing** **GE022**

1. Diameter and quantity of guide posts according to die size.

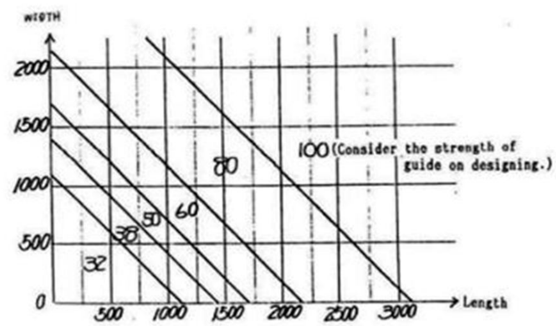



Fig. 11. Tata tool design standard for die guide design

Length of tool = 1000 mm
Width of tool = 1000 mm
So, Diameter of guide post = 38 mm

(1) For dies applying both heel guides and guide posts, fool proof should be placed on side preceding to be engaged.
(2) Fool proof should be placed on left side of die.
(3) In case of placing fool proof with heel guides, the dimensions of guiding part should be varied for 10 mm on right and left.

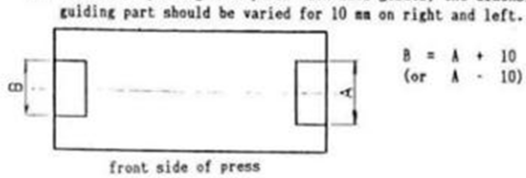
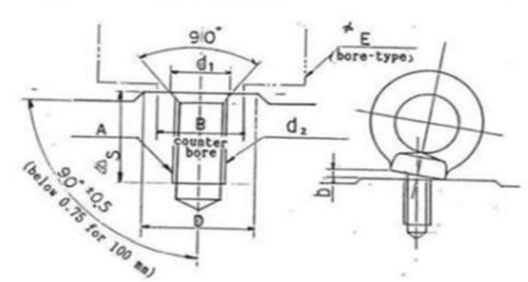



Fig. 12. Tata tool design standard for die guide design

∴ A = 38 mm and
B = A + 10= 38 + 10= 48 mm.

### H. Structure for Installing Eye Bolt

**Structure of installing eye bolt** **GE055**




| A | B | D | E | S | d2 | d1 | max.-b | Lift.Load 2 ropes(60°) | Lift. Load 4 ropes(60°) |
|---|---|---|---|---|---|---|---|---|---|
| M12 X 1.75 | 30 | 35 | 60 | 27 | 15 | 12.3 | 0.43 | ~ 250 | 500 |
| M16 X 2.0 | 35 | 40 | 70 | 35 | 19 | 14.3 | 0.52 | ~ 500 | ~ 1000 |
| M20 X 2.5 | 40 | 50 | 80 | 40 | 23 | 17.8 | 0.61 | 630 | ~ 1250 |
| M24 X 3.0 | 50 | 60 | 100 | 45 | 27 | 21.2 | 0.78 | 500 ~ 1100 | 1000 ~ 2000 |
| M30 X 3.5 | 65 | 70 | 120 | 55 | 35 | 26.8 | 1.05 | 1500 | ~ 3000 |
| M36 X 4.0 | 70 | 80 | 145 | 65 | 40 | 32.3 | 1.2 | 1000 ~ 2300 | 2000 ~ 4000 |

Fig. 13. Tata tool design standard structure for installing eye bolt

Weight of tool = 3066 kg
As we have die, blank holder and punch
∴ weight ÷ 3 = 3066 ÷ 3 = 1022 kg
We used 4 eye bolt as there are 4 ropes used
∴ 1022 ÷ 4 = 255.5 kg
So, we are going to used 4 bolt of
M12 X 1.75
B counter bore = 30 mm
D diameter = 35 mm
E bore type = 60 mm
S depth = 27 mm

### *I. Structure of Cushion Pins*

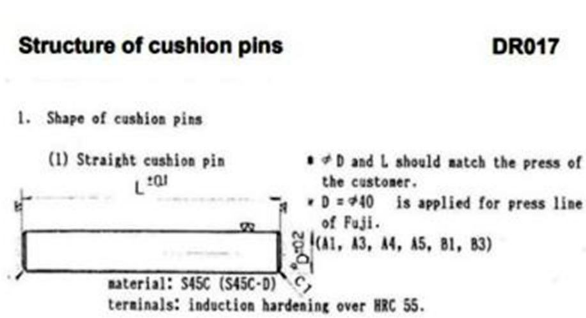



Fig. 14. Tata tool design standard of cushion pins

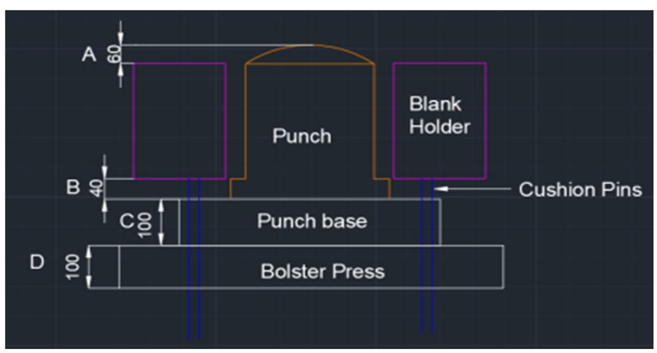



Fig. 15. Calculating cushion pins height

∅ D and L should match the press of the customer.
The hole diameter of the bolster 40 mm
Cushion pins should have less diameter as of the hole diameter of the bolster.
∴ D = 38 mm
S45C Steel is a medium strength steel usually supplied as solid round bar.
For Cushion pin height L,
Max height to min height A = 60 mm
Punch to blank holder B = 40 mm
Punch base plate C = 100 mm
Bolster press D = 100 mm
∴ Cushion pin height
L = A+B+C+D = 60+40+100+100=300 mm

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2. Deciding the number of cushion pins.

Examine the number of cushion pins to keep 5kg/mm² for unit pressure per a pin to prevent buckling or damage of cushion pin.

(1) In case of drawing

Required holding pressure ÷ (5kg x area of cushion pin)
= applied number

φ40 pin
5000 kg/pin

* The number should contain 20 - 30% surplus of calculated amount.

Fig. 16. Tata tool design standard for number of cushion pins

Weight of blank holder = 851.66 kg
Bottom press lifting capacity = 80 ton
As standard, 1 cushion pin can lift 5000 kg
But for balancing purpose only 1 cushion pin is not sufficient
∴ Minimum number of cushion pins
= weight ÷ (5kg x $\pi$D)
= 851.66÷ (5 x $\pi$ 38)
= 1.42

By calculation minimum no of cushion pin required is 2 and by design point of view to balance the load we considered 4 cushion pins.

## VI. CAD MODEL

Computer aided design is a use of computer to assist the creation modification of design. Cad software use to enhance the productivity of designer, improve communication through documentation and to create database for manufacturing. Cad output is always in the form of electronics for print and manufacturing operation

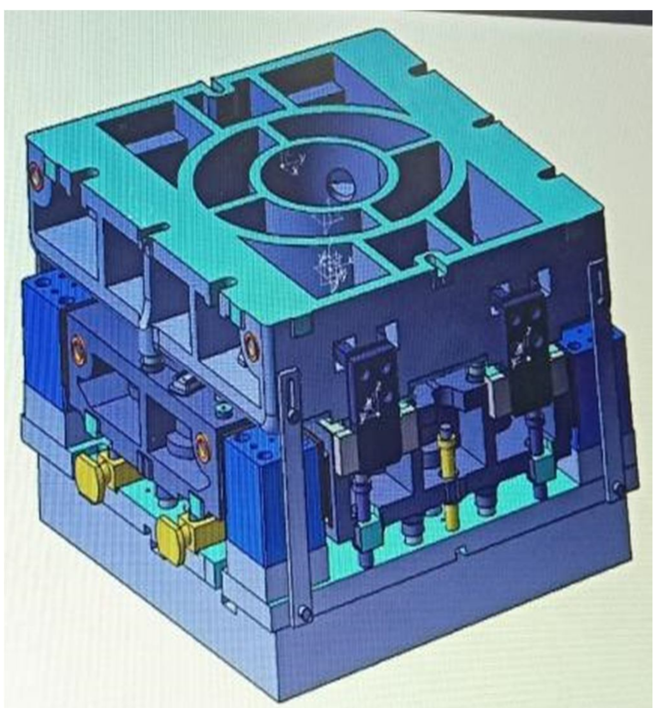

Fig. 17. CAD Model

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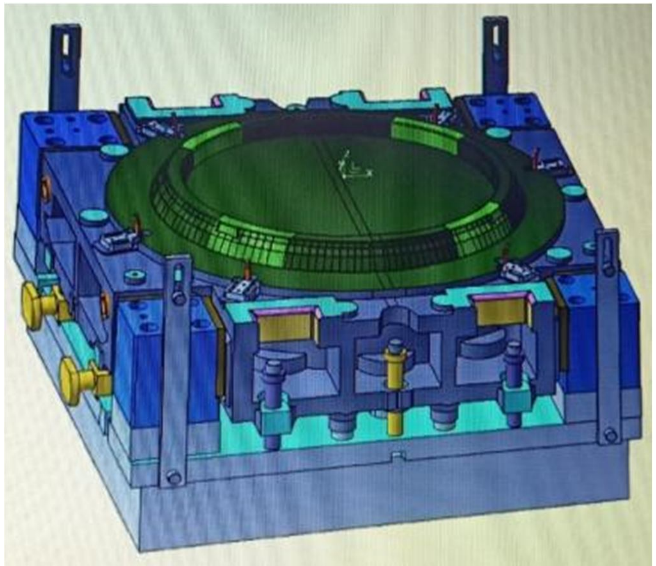

Fig. 18. Punch and blank holder

## VII. COMPONENTS OF TOOL

### *A. Upper Die*

Length = 1000 mm
Width = 1000 mm
Height = 250 mm
Depth = 60 mm

In this, die is used as a female portion to give exact shape to the blank as of the punch .It is made up of casting material FG 300 CrMo. Draw dies create the part shape by controlling metal flow into a cavity and over the forming punch .A die is a pre-shaped tool that works in conjunction with a press to manipulate the material into the desired size and shape. Dies are an essential tool used in the manufacturing industry. They work like molds to create objects in custom and often complex shapes.

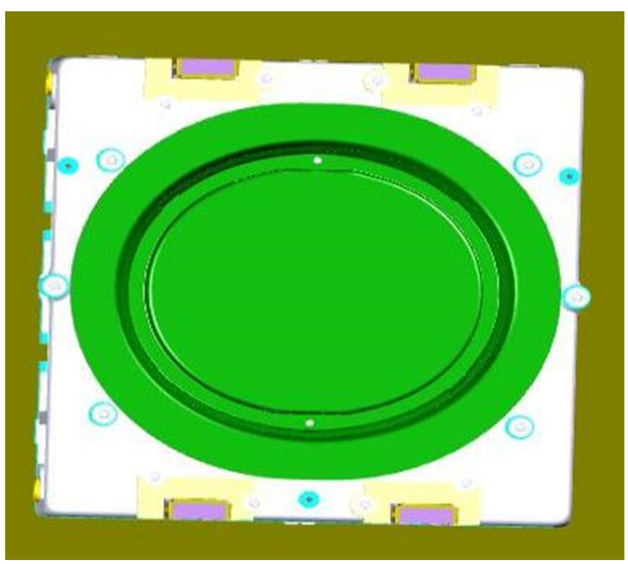

Fig. 19. Upper die

It is a thing that can be customized according to the requirement or necessity. Along with that, anything from simple to complex shapes can be made through a die.

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*B. Punch*

Length = 1000 mm
Width = 1000 mm
Height = 350 mm
In this, punch is used as male portion of the die which punches through the sheet metal and into the corresponding female section of the die block

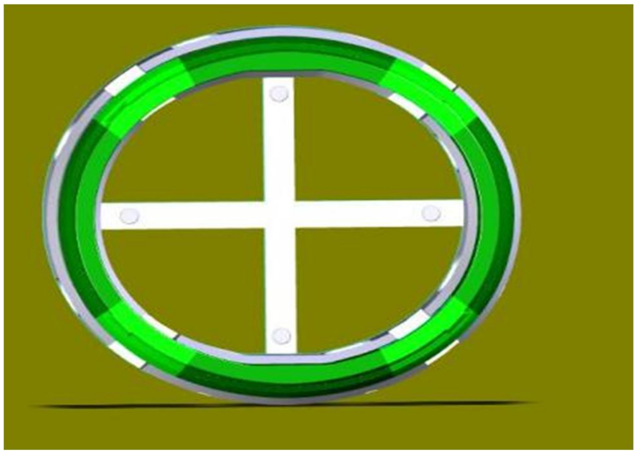

Fig. 20. Punch

Punch changes the size or shape of a piece of material, usually sheet metal, by applying pressure to a die in which the work piece is held. The form and construction of the die determine the shape produced on the work piece.
It is made up of casting material FG 300 MnCr.

*C. Blank Holder*

Length = 1000 mm
Width = 1000 mm
Height = 220 mm
It is made up of casting material FG 300 MnCr.

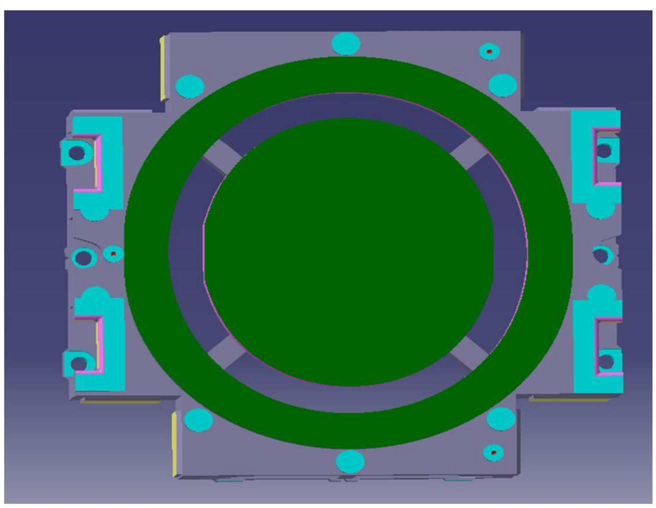

Fig. 21. Blank holder

In this blank holder is used to hold the blank. The material is compelled to thickening and wrinkling; this increases friction and requires more force. The blank holder simply prevent occurring wrinkling and the sheet is drawn more easily, so, blank holder mechanism is a key role of flow the material sheet.

 

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*D. Lifting Eye Bolt*

Diameter of eye bolt = 24 mm

In this, eye bolt are used to as a lifting source. Lifting Eyes bolt are simple, economical lifting devices suitable for fully vertical lifting in-line with the threaded bolt

Fig. 22. Lifting eye bolt

Eye bolts can be used as a connection point for rigging, anchoring, pulling, pushing, or hoisting applications. Although eye bolts are commonly used in industrial applications, they're also commonly misunderstood or used incorrectly.

*E. Guide Post*

In this guide post are used to identifying and operate the tool in appropriate way and direction.

4 guide post are there.

Left guide post = 38 mm

Right guide post = 48 mm

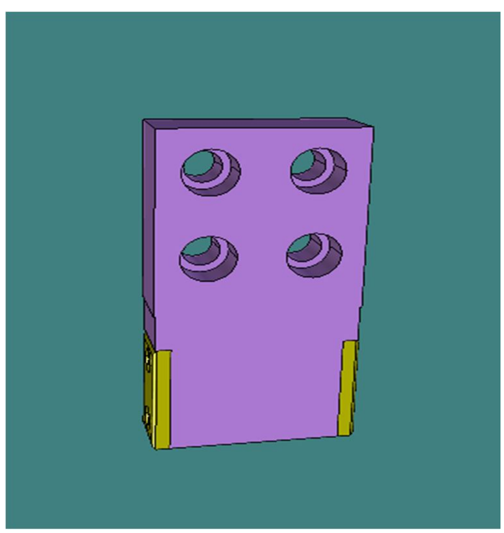


Fig. 23. Guide post

Guidepost of the press tool guide the die set to maintain the alignment during the operation. They improve tool operation and contribute to producing quality products. This is also called a pillar die set.

## VIII. RESULT AND DISCUSSION

On the basis of this experimentation the outcome shows the comparison of part formed by old tool and new tool. It shows the decreasing in rejection rate due to the implementation new tool. As the part has high rejection rate due to uncontrolled flow of forming, so there is a modification of tool by implementing the blank holder and draw bead which are used to control the forming flow. With this modification, we successfully achieved the elimination of the wrinkles from the part area by controlling the material flow in forming process. As the part form without any wrinkle, the rejection rate of the parts automatically goes down from 50 % to 0 .

### A. *Observation Tables*

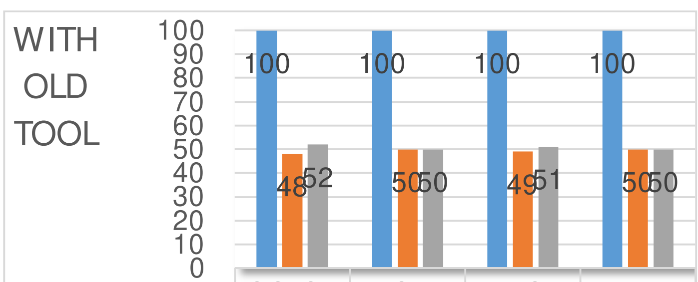
Table 2. Rejection rate of part with old tool

| Sr. No. | Month | Part form | Part with wrinkle | Rejection rate % |
|---|---|---|---|---|
| 1 | October | 100 | 52 | 52 |
| 2 | November | 100 | 50 | 50 |
| 3 | December | 100 | 51 | 51 |
| 4 | January | 100 | 50 | 50 |

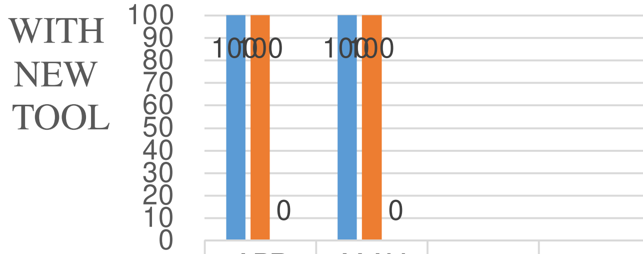
Table 3. Rejection rate of part with new tool

| Sr. No. | Month | Part form | Part with wrinkle | Rejection rate % |
|---|---|---|---|---|
| 1 | April | 100 | 0 | 0 |
| 2 | May | 100 | 0 | 0 |

### B. *Comparison Chart*




| | OCTOBER | NOVEMBER | DECEMBER | JANUARY |
|---|---|---|---|---|
| PART FORM | 100 | 100 | 100 | 100 |
| PART WITHOUT WRINKLE | 48 | 50 | 49 | 50 |
| PART WITH WRINKLE | 52 | 50 | 51 | 50 |




| | APR | MAY | | |
|---|---|---|---|---|
| PART FORM | 100 | 100 | | |
| PART WITHOUT WRINKLE | 100 | 100 | | |
| PART WITH WRINKLE | 0 | 0 | | |

## IX. CONCLUSION

In this study, a blank holder and draw bead concept of tool is used. It has been observed that the part formed by the new tool has rejection rate 0 as the wrinkle defect from the part is totally removed. The following conclusions can be obtained by presented study:

*1)* Adding the bead over blank holder restrict the flow of material.
*2)* Draw bead is necessary to avoid wrinkling of component.
*3)* Clearance between punch and die are equals to sheet thickness.
*4)* Addition of blank holder and bead are successfully implemented in the tool
*5)* Wrinkle defect are successfully minimized from 50 % to 0.
*6)* The effect factor of blank holder and bead are identified.
*7)* If draw bead are too far from finish part line, then it is unable to supply sufficient force to control the material whereas if it is too close from the part line then material pulled over bead to easily.

## X. FUTURE SCOPE

This research has great potential and should be carried further. Some suggestions for the future work are listed below:

*1)* In the present work, all the experiments were carried out with a single round bead. In future we can perform this experiment on double round bead, single square bead and double square bead as of the requirement of different parts and their geometry.
*2)* In future, the aerospace industry can used this tool according to their requirement to form the part without wrinkle.
*3)* The individual draw bead parameters i.e. draw bead radii, draw bead height on resolving wrinkling can be change so as to make modifications in the draw bead design based on required part to form.

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