Stress and strain analysis in cup drawing process for different materials using ANSYS

A project report submitted in partial fulfilment of the requirement for

the award of the degree of

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IN

MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Project Report entitled "**STRESS AND STRAIN ANALYSIS IN CUP DRAWING PROCESS FOR DIFFERENT MATERIALS USING ANSYS**" being submitted by GURRAM RAVI TEJA (317126520195), KALABARIGI KRISHNA NAGA SAI (317126520199), CHELLURI MANIKANTA (317126520188), BISAI SAIRAM (317126520186), MONANGI YASWANTH (317126520208) PADHY DINESH KUMAR (316126520101) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING, ANITS**. It is the work of bona-fide, carried out under the guidance and supervision of **DR.K.SIVA PRASAD**, Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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ABSTRACT

Sheet metal forming is widely used in automotive and aerospace sector. This project shows the analysis of sheet metal forming process mainly deep drawing. ANSYS simulation is used to carry out the results of difficult behaviour of the product. Main purpose of this project is to perform the static analysis on the deep drawing operation and to find the stresses, strains and total deformation. From theoretical values the dimensions of die and punch are obtained. Using these dimensions the CAD model is generated in CATIA. This assembly is then converted into .stp format and imported in ANSYS. The force required to develop the part, deformation and defect like tearing, wrinkles etc. can be obtained through simulation. By using this method it is easy to make stress and strain analysis for different materials

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CHAPTER- I
INTRODUCTION

1.1 METAL FORMING PROCESSES

Metal forming: Large set of manufacturing processes in which the material is deformed plastically to take the shape of the die geometry. The tools used for such deformation are called die,punch etc. depending on the type of process.

Plastic deformation: Stresses beyond yield strength of the workpiece material is required.

Categories: Bulk metal forming, Sheet metal forming stretching

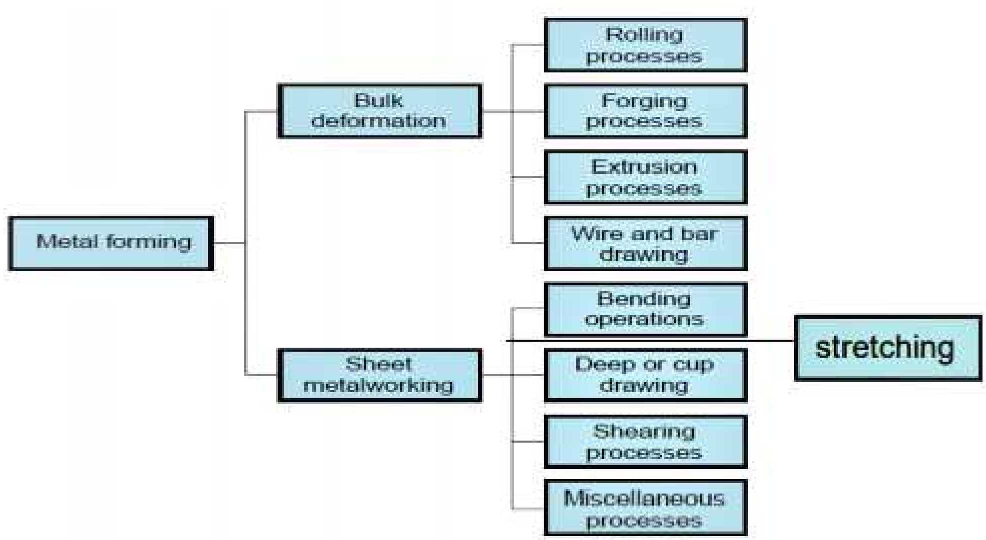


Fig 1.1 Classification of metal forming process

1.1.1 Classification of basic bulk forming processes

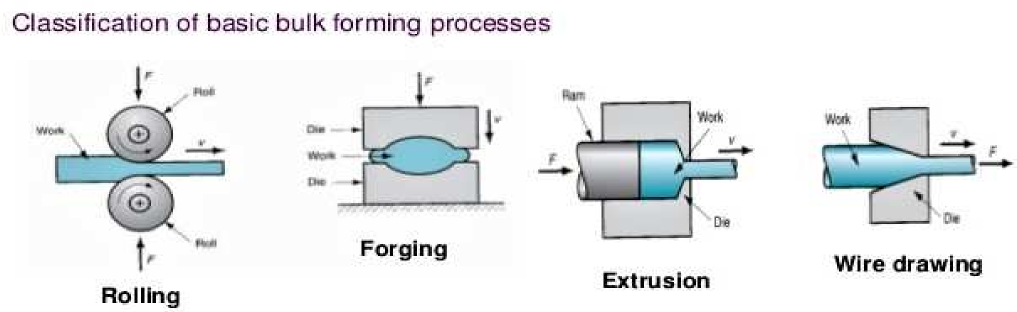


Fig 1.2 Classification of Bulk forming processes

Bulk forming: It is a severe deformation process resulting in massive shape change. The surface area-to-volume of the work is relatively small. Mostly done in hot working conditions

Rolling: In this process, the workpiece in the form of slab or plate is compressed between two rotating rolls in the thickness direction, so that the thickness is reduced. The rotating rolls draw the slab into the gap and compresses it. The final product is in the form of sheet.

Forging: The workpiece is compressed between two dies containing shaped contours. The die shapes are imparted into the final part.

Extrusion: In this, the workpiece is compressed or pushed into the die opening to take the shape of the die hole as its cross section.

Wire or Rod drawing: similar to extrusion, except that the workpiece is pulled through the die opening to take the cross-section

1.1.2 Classification of basic sheet forming processes

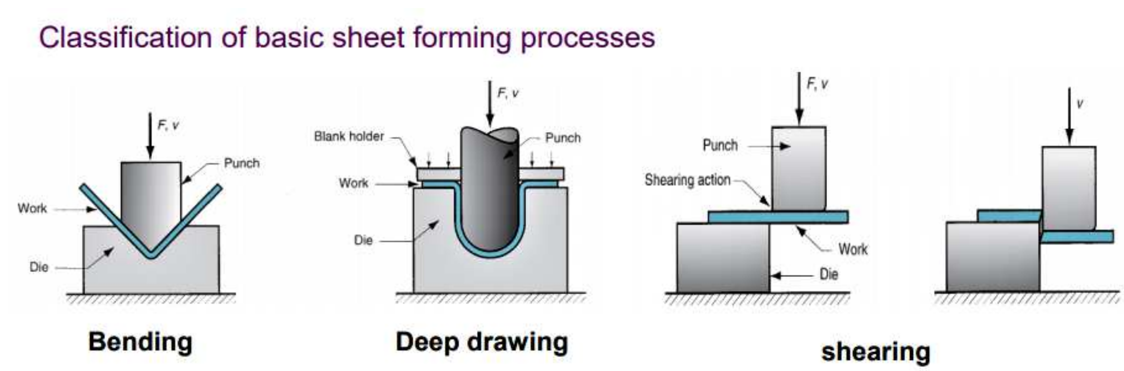


Fig 1.3 Classification of sheet forming processes

Sheet forming: Sheet metal forming involves forming and cutting operations performed on metal sheets, strips, and coils. The surface area-to-volume ratio of the starting metal is relatively high. Tools include punch, die that are used to deform the sheets.

Bending: In this, the sheet material is strained by punch to give a bend shape (angle shape) usually in a straight axis.

Deep (or cup) drawing: In this operation, forming of a flat metal sheet into a hollow or concave shape like a cup, is performed by stretching the metal in some regions. A blank-holder is used to clamp the blank on the die, while the punch pushes into the sheet metal. The sheet is drawn into the die hole taking the shape of the cavity.

Shearing: This is nothing but cutting of sheets by shearing action.

1.2 DEEP DRAWING OR CUP DRAWING PROCESS

Deep drawing is a process of converting metal sheet into cylindrical or box shaped structure with or without changing its length and thickness. Many cylindrical parts like metal can, pots, container for food and beverages, kitchen sinks, automobile fuel tank etc. are deep drawing product.

Before discussing its working process, first we should learn about main part used in drawing process. These parts are as follow.

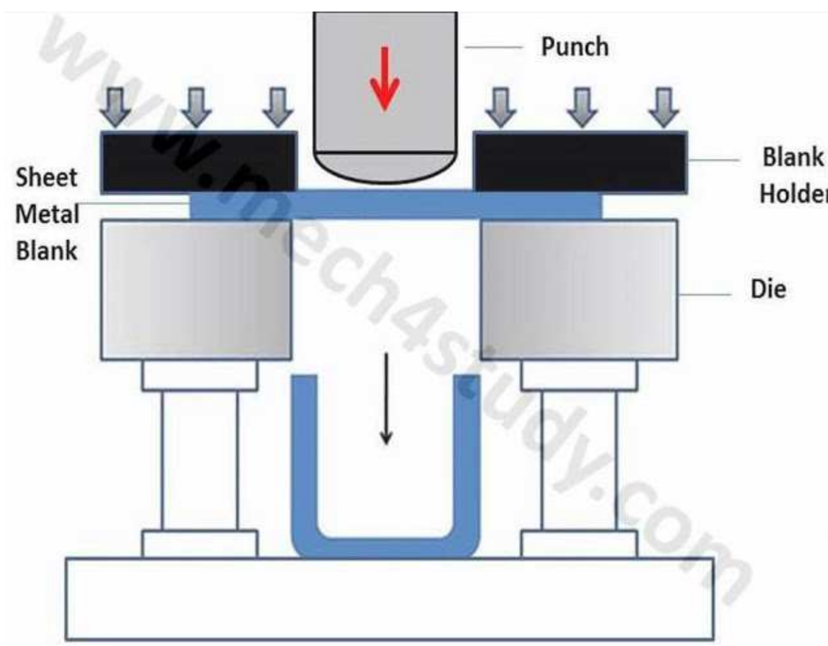


Fig 1.4 Deep Drawing Setup

Circular Die:

Sheet metal blank is placed over a circular die opening. This die is made by either tool steel or cast irons. Sometimes carbides and plastic are also used for die material.

Blank holder:

It is a part which holds the sheet metal blank at its required place. It provides necessary holding force during drawing. This force should not be as high which can cause tear of sheet metal during operation and also not too small which can cause tearing problem.

Punch:

This part provides necessary downward force at the blank. It travel downward and forces the blank into the die cavity to forming a cup shape. The diameter of the punch can be denoted by D_p

Blank:

The sheet metal cut piece which is used for deep drawing is known as blank. It is placed over an circular open die. The diameter of the blank is denoted by Do.

1.3 WORKING PROCESS

The blank is placed over an open circular die with the help of blank holder. The blank holder provides a necessary force to hold the blank. The punch which is attached with a mechanical or hydraulic press moves downward and provide a necessary drawing force at blank. This force tends to deform metal sheet and forces it into the die cavity and convert it into a cup shape structure. If this force is high it causes elongation of cup wall to thin and if excessive, it causes tearing of sheet. So the punch force should remain a certain limit to avoid tearing during operation.The Deep drawing assembly is shown in the below fig 1.5

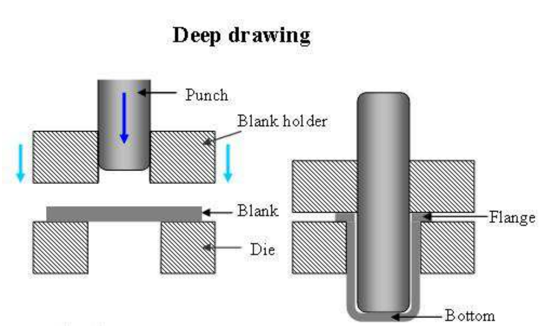


Fig 1.5 Deep Drawing

Deep drawing process depends on various parameters.

BLANK HOLDER FORCE AND CLEARANCE

The blank holder force (BHF) and clearance between punch and die should be carefully decided. Excessive BHF causes tearing, and too less BHF causes wrinkling. Clearance is usually 7%–15% of sheet thickness. Too less clearance causes ironing; sometimes, it may be desirable.

MATERIAL ANISOTROPY

Anisotropy of the sheet has a large influence on the deep drawing ability of the sheet. Planar anisotropy, in which properties differ with direction in the plane of the sheet, causes earlike formation on the drawn product; this defect is called earing. Normal anisotropy refers to the situation in which properties in the thickness direction differ from those in the plane of the sheet. A large flow stress in the thickness direction compared to that in the plane of the sheet provides better performance in deep drawing as it avoids tearing. A measure of normal anisotropy is the plastic strain ratio, which is the ratio of true width strain to true thickness strain for a material strained in the longitudinal direction. Automobile manufacturers prefer a plastic strain ratio of 1.4 or more for steel sheets.

LIMITING DRAWING RATIO

A measure of formability is the limiting draw ratio (LDR), which is the ratio of the diameter D of the largest blank that can be successfully drawn to the diameter of the punch d. Theoretical limit for LDR is 2.7

CLEARANCE BETWEEN PUNCH AND DIE:

Clearance between punch and die should be taken as 7 – 14% greater than sheet thickness. If this is too small it sheared or pierced the sheet blank.

CORNER RADIUS OF PUNCH AND DIE:

Corner radius can cause of wrinkling if it is too large and can causes fracture if it is too small. So this radius should take between these two limits.

LUBRICATION:

Lubrication lowers the forces, increases draw ability and reduces defect in the part and wear on the tooling. It does not provide on punch because friction between punch and blank improves draw ability by reduce tensile stress. Mostly used lubricants in deep drawing process are mineral oils, soap solutions, and heavy duty emulsions.

1.4 STRESS PATTERN IN DEEP DRAWING:

During the deep drawing process, different stress conditions result in the material. Figure 1.6 given below shows a drawn cup with the different loading zones. The zones of interest are

- Flange
- Side wall (cup wall),
- and its bottom.

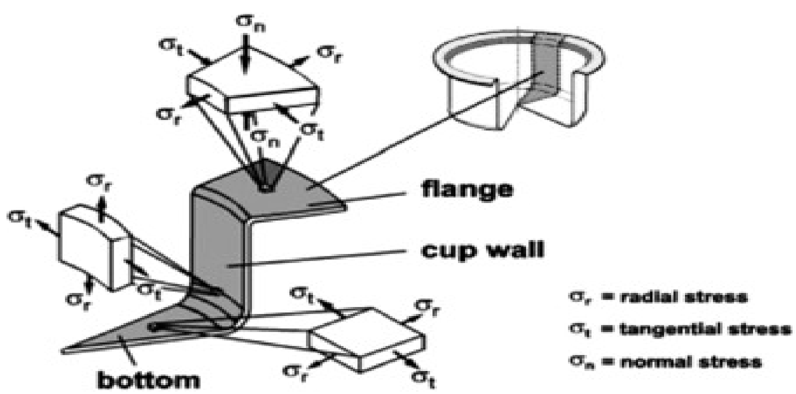


Fig 1.6 Stress Pattern

FLANGE REGION

The stress condition in the flange area is a tensile load in radial direction and compression load in tangential direction.The outer circumferences continuously decreases.This means the circumference of the blank is subjected to Compressive hoop stress.It is a plane stress deformation this is because only two stresses are acting on flange region.Thickening takes place in flange region. The stress conditions determine the forming process at deep drawing.

WALL REGION

The important stress condition in the cup wall is the point of transition of the punch radius to the cup wall area.Here the sheet is subjected to Bi-axial tensile stress. In the wall region the metal is bent and then straightened.

PUNCH BOTTOM REGION

Here the metal is getting thinned down,at the bottom of the punch.In the punch nose region sheet metal is subjected to plane strain deformation.

1.5 DEFECTS IN DEEP DRAWING:

The three major common defects which occur during this process are

- Fracture,
- Wrinkling
- and Earing.

Fracture occurs when the sheet metal is subjected to strains exceeding the safe strain limits of the material. For ductile sheets this fracture usually occurs near the punch corner .It is because maximum forming load appears in the material in this region and also stress concentration lines are converging in this section. Once this necking exceeds beyond a certain value, fracture appears in the drawn cup. A formed cup with fracture at the cup bottom is shown in Fig 1.7

Fig 1.7 Defects

Wrinkling occurs in the flange when compressive stresses in the circumferential direction reaches a critical point of instability. It can occur in regions where the work piece is unsupported or when the blank holding force is insufficient. Wrinkling defect is shown in Fig. The wrinkling can be prevented by increasing blank holder force and by using a draw bead. The draw bead bends and unbends the work piece material as it passes through the blank holder. This bending over the bead increases the radial tensile stresses and thus reduces the possibility of wrinkling.

Earing: Deep drawing of anisotropic sheets results in a drawn cup with uneven top edge i.e. some kind of ears are formed at the top as shown in Fig 1.8 This defect is called earing and it is because of planar anisotropy of the blank material.

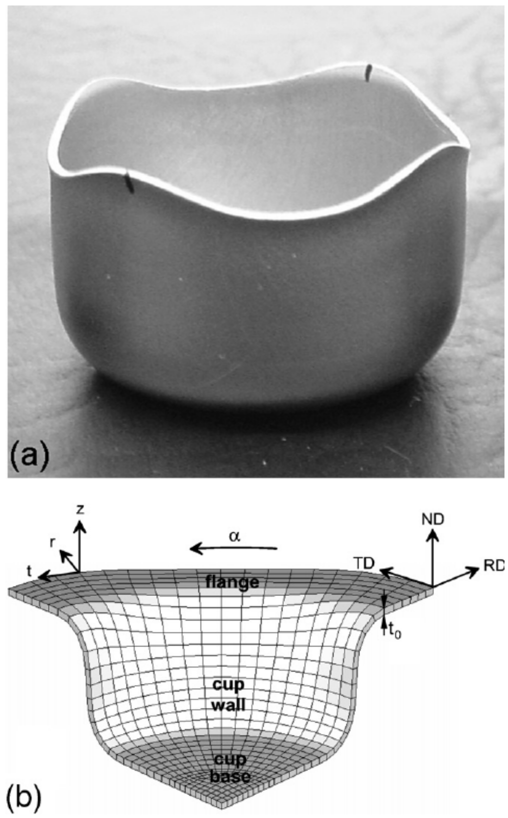


Fig 1.8 Earing defect

1.6 ADVANTAGESOF CUP DRAWING PROCESS:

1. Speed.

No other process can match the speed of a punch press moving up and down. It’s usually the most efficient method if you need a large quantity of parts making.

2. Eliminates assembly steps.

Deep drawing produces shapes with closed ends. That avoids the need to cut and weld multiple pieces.

3. Seamless.

A deep drawn can or tube shape has no joins. That makes deep drawing an ideal process for anything that needs to be water or gas-tight.

4. High accuracy.

Parts coming off a forming press are extremely repeatable. Assuming the tooling was made correctly, they'll also conform very closely to the drawing.

5. Produces complex geometries.

We've talked here about simple shapes like cans and sinks, but deep drawing can create more complex forms. How about the oil pan for an engine or complex filter housings?

6. Produces very strong parts

Many metals work-harden as they deform. Essentially, their crystal structure allows a certain amount of movement but beyond that it becomes locked. Deep drawing subjects metal to a lot of deformation, so can result in very hard finished parts.

1.7 DISADVANTAGES OF CUP DRAWING:

- Material thickness has a large effect on processing price.
- Special sleeves required to assist in driving the parts into dies.
- This process is expensive for low production rate.

CHAPTER-II

LITERATURE REVIEW

Mark Colgan, John Monaghan [1], reports on the initial stages of a combined experimental and finite element analysis (FEA) of a deep drawing process. The objective of this research was to determine the most important factors influencing a drawing process, using the help of a design of experiments and statistical analysis. The parameters varied include the punch and die radius, the punch velocity, clamping force, friction and draw depth.

S. Raju, G. Ganesan, R. Karthikeyan [2], 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. Cup 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. continuation of thickness variation in the formed part may cause stress concentration and may lead to hastening of damage.

Kopanathigowtham, K.V.N.S. Srikanth&k.L.N. Murty [3], reports on the initial stages of finite element analysis(FEA) of a Deep drawing process. The objective of this study was to determine the factors influencing a drawing process and analyzing the process by varying the Die radius and keeping the Friction, Punch radius and Blank Thickness as constant. In this paper Punches, blank thickness of same geometry and dies of various geometries were drawn by using CATIA software. And an effort is made to study the simulation effect of main process variant namely die radius using finite element analysis.

R. Padmanabhan, M.C. Oliveira, J.L. Alves, L.F. Menezes [4], in his studies revealed that to determine the optimum values of the process parameters, it is important to find their manipulate on the deformation behaviour of the sheet metal. The importance of three significant process parameters namely, the die radius, blank holder force and friction coefficient on the deep-drawing characteristics of a stainless steel axi-symmetric cup was resoluted Finite element method combined with Taguchi technique form a refined predictive tool to determine the influence of forming process parameters. This paper illustrates the use of FEM with Taguchi technique to determine the proportion of contribution of three important process parameters in the deep-drawing process namely die radius, blank holder force and friction coefficient.

R. Venkat Reddy, Dr T.A. Janardhan Reddy, Dr. G.C.M. Reddy [5], studied that the appearance of dimensional deviations of shape and position, of the defects in the metal sheets that have been subjected to a cold plastic deformation process (deep drawing), represents a critical problem for the mass production, like the machine manufacturing industry. The aim of this publication was to present the principal aspects that effect of various factors like BHF, punch radius, die edge radius, and coeffcient of friction on the wrinkling of cylindrical parts in deep drawing process.

Y. Marumo, H. Saiki, L Ruan [6],The objective of the work was to study the influence of sheet thickness on blank holding force and limiting drawing ratio. The paper shows variation in the blank holding force required for the elimination of wrinkling and the limiting drawing ratio with sheet thickness. The blank holding force required for the elimination of wrinkling increased rapidly as the sheet thickness decreased. The blank holding force was strongly influenced by sheet thickness and the coefficient of friction. The limiting drawing ratio decreased as sheet thickness decreased.

A.FallahiArezodar and A. Eghbali [7],stated that deep drawing process has some noticeable defects such as wrinkling, tearing, spring back, and thickness variation in different locations of produced cups. In the research the parameters of interest were punch/die shoulder radius, blank holder force, friction between sheet and die/punch/holder.

A.R.Joshi et al [8], In this paper basic review is presented based on optimization of process parameter in deep drawing process with the use of different techniques. The formability of sheet metals is affected by many parameters, like material parameters,process parameters and strain bounding criteria. Optimization of process parameters in sheet metal forming is an important task to reduce manufacturing cost.

To determine the optimum values of the process parameters, it is essential to find their influence on the deformation behaviour of the sheet metal.

Young Hoon Moon, Yong Kee Kang, Jin Wook Park, Sung Rak Gong [9], studied the effects of internal air-pressing on deep draw ability to increase the deep drawability of aluminum sheet. The predictable deep drawing process is limited to a certain limit drawing ratio(LDR) beyond which failure will occur The intention of this work was to examine the possibilities of relaxing the above limitation through the deep drawing with internal air-pressing, aiming towards a process with an increased drawing ratio. The equipment and tooling parameters that affect the success or failure of a deep drawing operation are the punch and die radii, the punch and die clearance, the press speed and the lubrication.

Saniee, F.F., Montazeran, M.H[10].The deep drawing process is one of the important sheet-metal forming processes. Using this operation, many parts are manufactured in various industries. In this paper, different methods of analysis such as analytical, numerical and experimental techniques are employed to estimate the required drawing force for a typical component. With this regard, the numerical simulations were conducted using the finite-element (FE) method. In these simulations, the effects of the element type on the forming load and the variation of the thickness strain were studied.

Verma, R., Chandra[11] During the material selection and the tool design stage for a new component the knowledge of formability of the material under consideration is required. Limiting drawing ratio is one such measure.This paper emphasizes on limiting drawing ratio.

Alexander J.M[12].The term “deep drawing” is generally understood to apply to the process of deforming sheet metal that is characterized by the use of a punch and a die, the sheet being drawn inwards and over the die profile by the advancing punch whilst the flange is controlled by moderate “blank-holding” pressure supplied by a suitably shaped blank-holder. Pressing, stretch-forming, beading, and embossing differ from deep drawing in that the edges of the material are generally prevented from being drawn in.

Li Y Q, Cui, Z S, Ruan X Y, Zhang D J[13] Optimization method and numerical simulation technology have been applied in sheet metal forming process to improve design quality and shorten design cycle. However, deterministic optimization may lead to unreliable and non-robust design due to not considering the fluctuation of design variables, environments and operation conditions, etc. In addition to that, iterations in optimization process may cause numerous simulation time or expensive experiment cost

P.VR.RavindraReddy ,G.ChandraMohanReddy ,TA.JanardhanReddy [14] In deep drawing metal sheet is subjected to high punch pressure which causes deformation of material, during deformation stresses are generated in various zones, which leads to various defects. The predominant failure modes in sheet metal parts are wrinkling and fracture. Existence of thickness variation in the formed part may cause stress concentration and may lead to acceleration of damage .Simulation and FEM analysis of the process by varying process parameters can interpret concentration of flowing stresses during deep drawing process in advance before actual production of parts, thus anticipation of defect free product can predicted before actually going for production.

N. C. Mehta, Viral V. Shiyani, Jemish R. Nasit[15] This paper mainly focuses physical defects which occur during metal forming processes. These defects, which may occur on the surface or be internal, are undesirable not only because of the surface appearance, but because they may adversely affect the strength, formability and other manufacturing characteristics of the material. Some physical defects in metal forming processes such as rolling and forging, Defects in forging reduce its strength. Appreciable residual stresses and warping can occur on the quenching of steel forgings in heat treatment

Brabie G, Nanu N, Radu ME [16]This paper investigates the influence of the punch shape on springback intensity and residual stresses distribution by simulating the drawing process in the case of conical parts made from steel sheets by using the following two punch shapes: cylindrical and conical

Chandra Pal Singh, Geeta Agnihotri[17] This paper is highlighting recent research work and results in deep drawing. Deep-drawing operations are performed to produce a light weight, high strength, low density, and corrosion resistible product. These requirements will increase tendency of wrinkling and other failure defects in the product. Parameters like as blank-holder pressure, punch radius, die radius, material properties, and coefficient of friction affect deep drawing process.

Adnan I. O. Zaid[18]In this paper, the effect of lubrication on the deep drawing process is investigated which includes: the effects on the force, energy requirements and the quality of the deep drawn cylindrical steel cups. The quality is assessed by the reduction in the amount of thinning, wrinkling, the height of ears and the bell shape. Five different lubricants were used

Najmeddin Arab, Abotaleb Javadimanesh[19],This paper deals with the analysis of deep drawing of circular blanks into axi-symmetric cylindrical cup using numerical modeling. The blank draw ability has been related both theoretically and experimentally with the initial diameter of the blank and deep drawing parameters. The strains in the radial and circumferential directions have been measured.

Sanjay K. Ansodariya Bharat J. Kapadiya[20] The study aims to determine the optimum blank shape design for deep drawing of arbitrary shaped cups with a uniform trim allowance at the flange, i.e., cups without ears. The earing, or non-uniform flange, is caused by non-uniform material flow and planar anisotropy in the sheet. Drawing is sheet metal forming operation used to make cup shaped, box shaped, and complex curved and concave cup.

Aniruddh Shukla , Dr Dharmendra Tyagi[21] presents a new technique for deep drawing of cylindrical cups and the aim of this work is investigation of sheet metal forming using a punch with blank-holder. In this technique a cylindrical cup is produced by pushing a circular blank using a flat-headed circular punch through a cylindrical die. Effects of die and punch geometry including, coefficient of friction, blank-holder pressure, punch velocity, drawing load and thickness strain of the cup have been investigated numerically for optimal process design.

Jenn-Terng Gau,SujithTeegala, KunMin Huang,d, Tun-Jen Hsiao, BorTsuen Lin[22] A series of experiments were conducted by using the stainless steel 304 sheets of 200 μm thickness annealed at four different temperatures to understand the influence of size effects on this process for generating knowledge, know-how and technologies to form high quality stainless steel micro cups with large CH/OD ratio. No lubricant was used in this study. It was proven that the proposed

H. Gharib,A.S. Wifi,M. Younan, A. Nassef[23] The research presented in this paper offers a new optimization strategy which can be useful incontrolling the process parameters to produce a defect free deep drawn part using optimum process conditions.

Pradipkumar Patil, K.H.Inamdar[24] The finite element method is a powerful tool to predict material thinning deformations before prototypes are made. In this paper, thinning defect has been considered for a rectangular shaped part and simulation has been carried out

Ravindra K.Saxena, P.M. Dixit[25] The occurrence of ductile fracture is often a limiting factor in metal forming processes. Prediction of the initiation of ductile fracture allows a prior modification of the process which can result in a defect-free final product with financial savings. The intensity of voids is often represented by introducing a variable called damage. This paper deals with the prediction of fracture initiation in deep drawn cup.

Suresh Kurra, Srinivasa Prakash Regalla[26] This paper focuses on the formability and thickness distribution in incremental sheet forming (ISF) of extra-deep drawing steel (EDD). Theoretical and simulated thickness values have been compared with measured thickness values. It was found from the results that the finite element model was more accurate than theoretical model in predicting thickness distribution.

V.Malikova,,R.Ossenbrink,B.Viehweger,V. Michailov[27] In this study the change of the stiffness of the structured sheet metal during the deep drawing is investigated. Two cases are considered: deep drawing and compression. The results show a significant change of the geometry and mechanical properties of the structured sheet metal in both cases. The relationships between the flattening and stiffness properties in both cases were discussed in detail.

Patil P.M.Bajaj P. S.[28]This paper reports on the initial stages of a combined experimental and finite element analysis (FEA) of a deep drawing process. A deep drawing rig was designed and built for this purpose. Punches and dies of various geometries were manufactured. It has also been observed from the work to date that the speed of drawing plays an interesting role, in so far as, the higher is the speed the further is the draw.

Magar, S.M., Ghanegaonkar, P.M., Vikhe, G.J[29] This book describes the approach of Analytical, Numerical and Experimental study of Deep Drawing process, on the basis of parameters selected from tooling industry point of view. Analytically studied parameters are: Stress, Punch force, Blank holder force and Initial Blank size. For Experimental study, two cylindrical components are drawn and parameters studied are: formability, thickness distribution, major and minor strain in cup wall. Classification of various Finite Element Analysis softwares is studied.

Shishir Anwekar, Abhishek Jain[30] In the presented study, simulation of the drawing process for determining strain distribution pattern in the drawn component for a particular displacement is explained. The study was conducted by using ANSYS12.0, in which, two models have been tested. Both models constructed solely out of axisymmetric, quad 4 node, PLANE 42 elements.

2.1 SUMMARY OF LITERATURE REVIEW

There are many processing and material parameters which are affecting deep drawing process. Some of the functions are there which cover most of the material and processing parameters affecting the thickness distribution and also the quality of the product. During the last decade many researchers have provided those functions which increase the efficiency of the process and reduce the undesirable features like earing and wrinkles. Some of the functions which are covering most of the material and processing parameters and also the effect of different material and processing parameters are shown.

After studying the above literatures we have concluded that following process parameters are taken place in deep drawing process.

1. Radius on Punch
2. Radius on Die
3. Friction
4. Material to be drawn
5. Blank holding force
6. Die clearance
7.Stress and Strain Distribution

CHAPTER-III
DESIGN CALCULATIONS

3.1 NOMENCLATURE

r1 : radius to the mean surface of sheet at the moving boundary between regions III and IV

r2 : radius to the mean surface of sheet at the moving boundary between regions IV and V

ra : current rim radius

rb : current boundary radius of the rim region between regions I and II

rc : radius to the die lip

rd : die throat radius

re : punch radius

rf : radius of the flat base of punch

rm : average radial position of two points

$\varepsilon\theta, \varepsilon r, \varepsilon t$: principal circumferential, radial and thickness strains respectively

εequ : equivalent strain

$\sigma\theta, \sigma r, \sigma t$: principal circumferential, radial and thickness stresses respectively

σequ : Von Mises yield stress

3.2 DIMENSIONS OF ASSEMBLY

Table 3.1 Dimensions of the Assembly

SNO	PART NAME	MATERIAL	DIMENSIONS(in mm)
1.	BLANK	Aluminium,Copper, Titanium	Radius:45 Thickness:2
2.	BLANK HOLDER	Structural steel	Inner radius:20 Outerradius:40 Thickness:5
3.	DIE	Structural steel	Height:20 Fillet radius:2.5 Inner radius:17 Outer radius:40
4.	PUNCH	Structural steel	Radius:15 Height:20 Fillet radius:2.5

3.3 FORMULAE

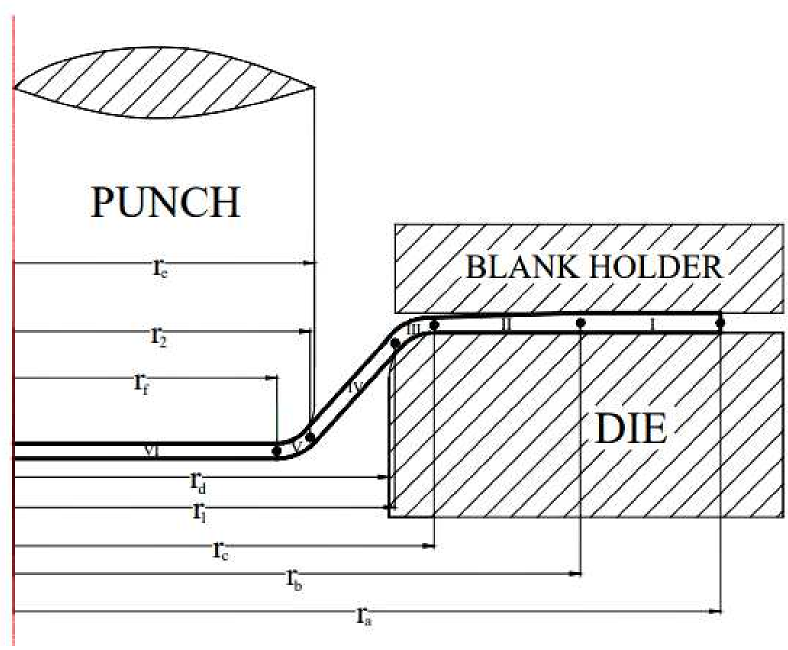


Fig 3.1 Dimensions

Region I - (Flange in contact with the blank-holder)

Region II - (Flange not in contact with the blank-holder)

Region III - (Die Profile)

Region IV - (Straight Wall)

Region V - (Punch Profile)

Region VI - (Flat Bottom below the punch)

Region I (Flange in contact with the blank-holder): It consists of the part of the material present over the die where it experiences a state of radial drawing under friction with the blank holder and the die surface. In this region, wrinkling or local buckling of the sheet blank due to compressive stress is possible. So, the blankholder role is to press normally on this area to suppress wrinkling of the flange and forces the sheet to have a constant thickness.

Region II (Flange not in contact with the blank-holder): This is the remaining part¬ of the flange undergoing radial drawing. The material in this region is not in contact with the blank holder. Thus, thickness variation is possible, where the material starts with a large thickness at radius rb and thins until it reaches radius rc (die lip).

Region III (Die Profile): This region undergoes both radial drawing with friction¬ over die profile and bending/unbending effect. This combined loading causes sudden decrease in thickness at the die lip (radius rc). The position of the point of departure of the material from the die profile to the wall of the cup (radius r1) is varying through time. This represents a problem with a moving boundary, which is not known a priori in the analysis and requires special treatment to determine its correct position.

Region IV (Straight Wall): this region forms the wall of the cup where it starts from the departure of sheet from the die profile until it meets the punch profile at radius r2. The material in this region suffers a state of biaxial stress. The point of contact of the sheet with the punch profile (at radius r2) is also considered a moving boundary.

Region V (Punch Profile): This region constitutes the part of the sheet being stretched under friction and bent over the punch profile. Fracture of the sheet metal usually occurs at the boundary between this region and region IV.

Region VI (Flat Bottom below the punch): Material is drawn under biaxial state of¬ stress in this region. Stresses and strains are nearly uniform and constant over this area.

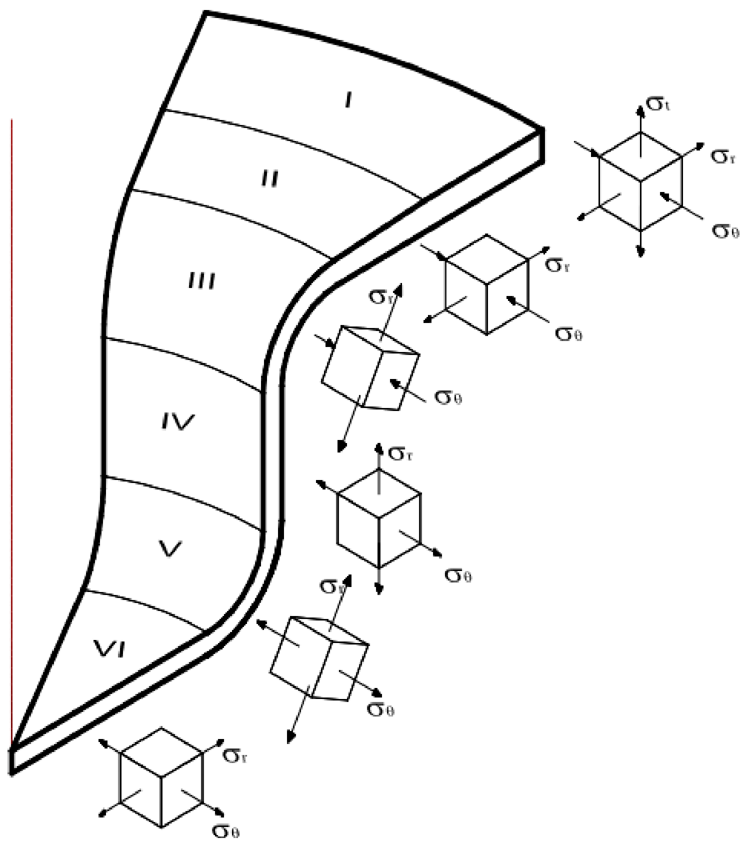


Fig 3.2 stresses in various regions of formed cup

Table 3.2 Cross-sectional areas of different regions

Region	Cross section area
I	$a_I = \pi\left(r_a^2 - r_b^2\right)$
II	$a_{II} = \pi\left(r_b^2 - r_c^2\right)$
III	$a_{III} = 2\pi\lambda_d \rho_d^{'} \theta$ Where, $\lambda_d = r_d + \rho_d - \rho_d^{'} \dfrac{(1-\cos\theta)}{\theta}$ = the centroid of the curved surface on the die profile
	$a_{IV} = 2\pi\lambda_W T$ Where, $\lambda_W = r_f + \left(\rho_p^{'} \tan\theta + \dfrac{1}{2}T\right)\cos\theta$ = the centroid of the wall
V	$a_V = 2\pi\lambda_p \rho_p^{'} \theta$ Where, $\lambda_p = r_f + \rho_p^{'} \dfrac{(1-\cos\theta)}{\theta}$ = the centroid of the curved surface on the punch profile
VI	$a_{VI} = \pi r_f^2$

Effective Stress

Von Mises or effective stress is defined as follows:

$$\bar{\sigma} = \sqrt{\frac{1}{2}\left[(\sigma_r - \sigma_\theta)^2 + (\sigma_\theta - \sigma_t)^2 + (\sigma_t - \sigma_r)^2\right]}$$

Plastic Strains

Plastic strains for the three principal directions; circumferential, thickness, and radial (meridional) directions can be expressed as

$$\varepsilon_\theta = \ln\left(\frac{r}{R}\right)$$

$$\varepsilon_t = \ln\left(\frac{t}{t_o}\right)$$

From the condition of constancy of volume:

$$d\varepsilon_r + d\varepsilon_\theta + d\varepsilon_t = 0 \quad , \quad \varepsilon_r + \varepsilon_\theta + \varepsilon_t = 0$$

$$\varepsilon_r = -\varepsilon_\theta - \varepsilon_t$$

Effective Strain

The effective incremental strain can be stated as:

$$d\bar{\varepsilon} = \sqrt{\frac{4}{3}\left[(d\varepsilon_\theta + d\varepsilon_t)^2 - d\varepsilon_\theta d\varepsilon_t\right]}$$

Stress-Strain Relationship

The Levy-Lode stress-strain relationship states that:

$$\frac{d\varepsilon_r - d\varepsilon_\theta}{\sigma_r - \sigma_\theta} = \frac{d\varepsilon_\theta - d\varepsilon_t}{\sigma_\theta - \sigma_t} = \frac{d\varepsilon_t - d\varepsilon_r}{\sigma_t - \sigma_r} = \frac{3}{2}\frac{d\bar{\varepsilon}}{\bar{\sigma}}$$

Hence, the stress-strain relations can be written as:

$$\sigma_\theta - \sigma_r = \frac{2}{3}\frac{\bar{\sigma}}{d\bar{\varepsilon}}(d\varepsilon_\theta - d\varepsilon_r) = \frac{2}{3}\frac{\bar{\sigma}}{d\bar{\varepsilon}}(2d\varepsilon_\theta + d\varepsilon_t)$$

$$\sigma_t - \sigma_r = \frac{2}{3}\frac{\bar{\sigma}}{d\bar{\varepsilon}}(d\varepsilon_t - d\varepsilon_r) = \frac{2}{3}\frac{\bar{\sigma}}{d\bar{\varepsilon}}(2d\varepsilon_t + d\varepsilon_\theta)$$

CHAPTER-IV
MODELLING AND SIMULATION

In this project we have chosen CATIA for 3D modelling

ABOUT CATIA

CATIA is an acronym for **C**omputer **A**ided **T**hree-dimensional **I**nteractive **A**pplication. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.

CATIA is a multi platform 3D software suite developed by Dassault Systems, encompassing CAD, CAM as well as CAE

CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bi-directionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa.

4.1 CATIA for various Disciplines

The products developed today are getting increasingly complex. Users are demanding better performance and quality from them. This compels manufacturers to come up with engaging technical solutions and that too at a rapid pace. The engineering solutions from CATIA answers that challenge, enabling the rapid development of high-quality mechanical products

CATIA from Dassault is a diverse application that offers a complete engineering toolset for various disciplines within a single working environment. What is more, the workbenches (as CATIAs modules are called) provide a seamless and consistent user interface across multiple disciplines.

4.1.1 CATIA for Mechanical Engineering

CATIA 3D modeling tools provide mechanical engineers with valuable insights into key factors of quality and performance early in the product development phase. Digital prototyping, combined with digital analysis and simulation, allows product development teams to virtually create and analyze a mechanical product in its operating environment. CATIA's mechanical design products allow the user to create parts in a highly productive and intuitive environment, to enrich existing mechanical part design with wireframe and basic surface features. CATIA also provides advanced drafting capabilities through the associative drawing generation from 3D part and assembly designs. Mechanical Design products can address 2D design and drawing production requirements with a stand-alone state-of-the-art 2D tool Interactive Drafting

Key Benefits

- Create any type of 3D part, from rough 3D sketches to fully detailed industrial assemblies.
- Unbreakable relational design - a new way to manage links between objects and related behaviors in configured assemblies.
- Enables a smooth evolution from 2D- to 3D-based design methodologies.
- Productive and consistent drawing update removes the need for additional user operations.
- Process oriented tools capture the manufacturing process intent in the early stages of design.
- A wide range of applications for tooling design, for generic tooling in addition to mold and die.
- Advanced technologies for mechanical surfacing, based on a powerful specification-driven modeling approach

4.1.2 CATIA for Design / Styling

From product to transportation industries, the style & design of the product plays a major role in its success on the market. Develop shape & material creativity, reach a high level of surface sophistication & quality, and get the right decision tools with physical & virtual prototypes. These are the key elements of CATIA Design/Styling to boost design innovation.

From 3D sketching, subdivision surface, Class-A modeling to 3D printing, reverse engineering, visualization and experience, CATIA Design/Styling provides all the solutions for design creativity, surface excellence and product experience.

Key Benefits

- **Industrial Design:** whether starting 3D ideation from scratch or from 2D sketches, industrial designers can manipulate shapes with unrivaled freedom and take advantage of a true creativity accelerator to explore more ideas in the early conceptual phase.
- **Advanced Surface Modeling:** fully addresses the Automotive Class-A shape design process with a solution for surface refinement that integrates industry-leading Icem surfacing technologies. Delivers a powerful and intuitive suite of tools for modeling, analyzing and visualizing aesthetic and ergonomic shapes for the highest Class-A surface quality.

Since it is feature rich – regardless of the discipline you would like to work on – training on how to use CATIA is very important to derive maximum benefits from the software.

4.2 VARIOUS MODULES

CATIA offers many workbenches that can be loosely termed as modules. A few of the important workbenches and their brief functionality description is given below:

Part Design: The most essential workbench needed for solid modelling. This CATIA module makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to iterative detailed design.

Generative Shape Design: allows you to quickly model both simple and complex shapes using wireframe and surface features. It provides a large set of tools for creating and editing shape designs. Though not essential, knowledge of Part Design will be very handy in better utilization of this module.

Assembly: The basics of product structure, constraints, and moving assemblies and parts can be learned quickly. This is the workbench that allows connecting all the parts to form a machine or a component.

Kinematic Simulation: Kinematics involves an assembly of parts that are connected together by a series of joints, referred to as a mechanism. These joints define how an assembly can perform motion. It addresses the design review environment of digital mock-ups. This workbench shows how a machine will move in the real world.

These are only four of the many workbenches that CATIA offers. A few of the other modules include Machining, Equipment & System, Infrastructure and Ergonomics Design & Analysis.

4.3 MODELLING IN CATIA:

Sketching:

1.**Die**: Select the work plane in front view and draw the necessary sketch for body with given dimensions and revolve it using shaft command to obtain the body. The below fig 4.1 shows the Die part obtained in CATIA

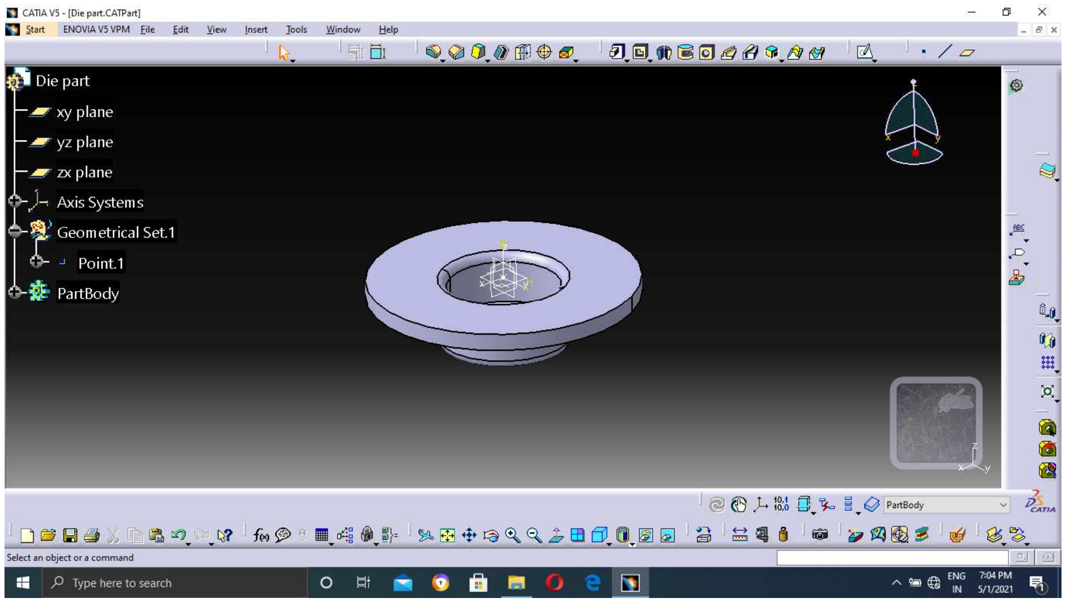


Fig 4.1 Die

2.**Blank Holder**: Select the work plane in front view and draw the necessary sketch for blank holder with given dimensions and revolve it using shaft command to obtain the body.The below fig 4.2 shows the blank holder part obtained in CATIA

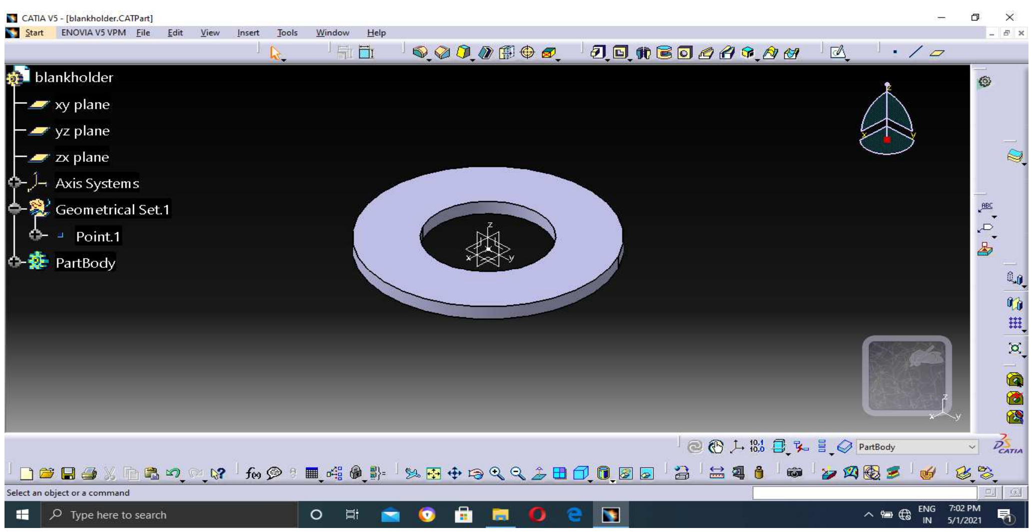


Fig 4.2 Blank holder

3.**Punch**: Select the work plane in front view and draw the necessary sketch for punch with given dimensions and revolve it using shaft command to obtain the body.Punch head is also added to punch for stability. The below fig 4.3 shows the punch part obtained in CATIA

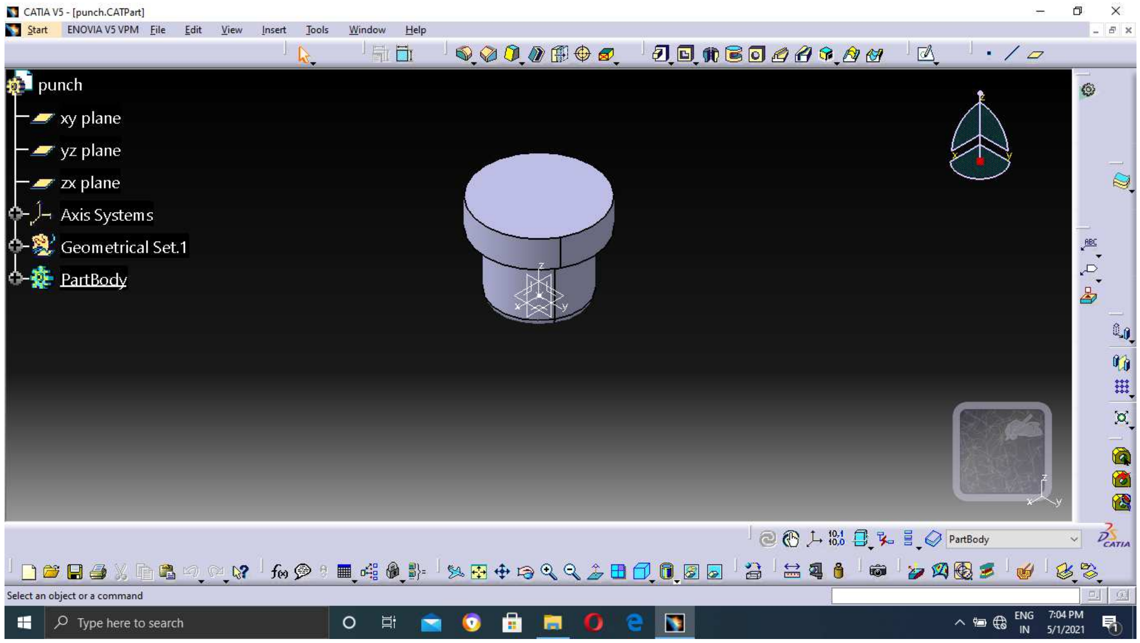


Fig 4.3 punch

4.**Blank**:Designing of blank is done generative sheet metal design work bench.Sheet metal parameters are adjusted.Select the work plane in front view.Draw the sketch for blank with given dimensions. The below fig 4.4 shows the blank part obtained in CATIA

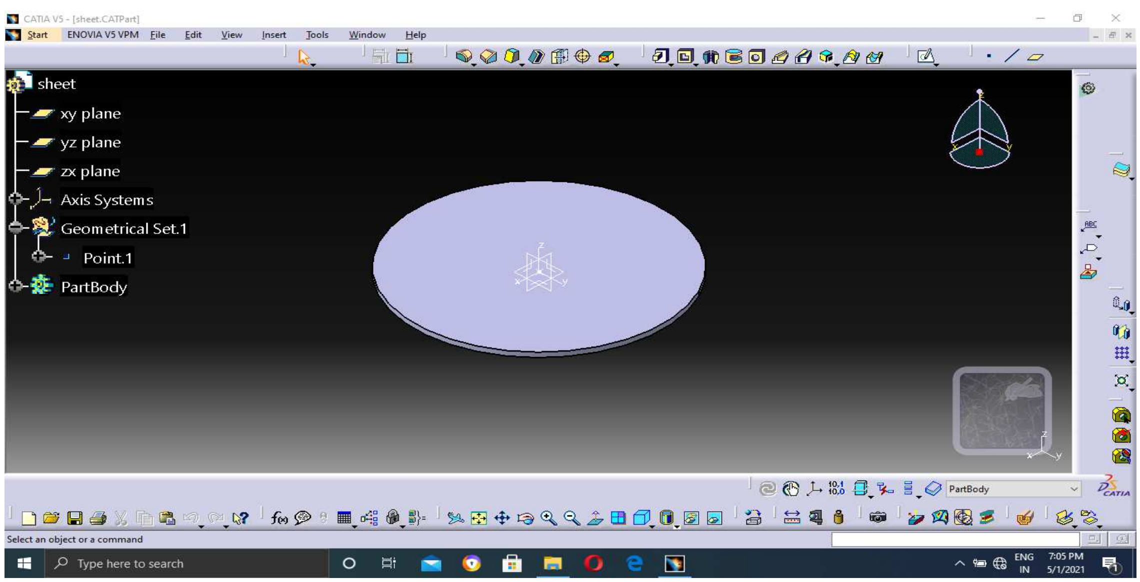


Fig 4.4 blank

4.3.1 Assembly

All the individually produced components are now put together and are assembled to produce the final product which is as shown in the below fig 4.5

All the parts are inserted into the assembly workbench.

All the components are assembled by using surface contact and offset constraints.

The axes of the mating components are aligned priorly before using these constraints.

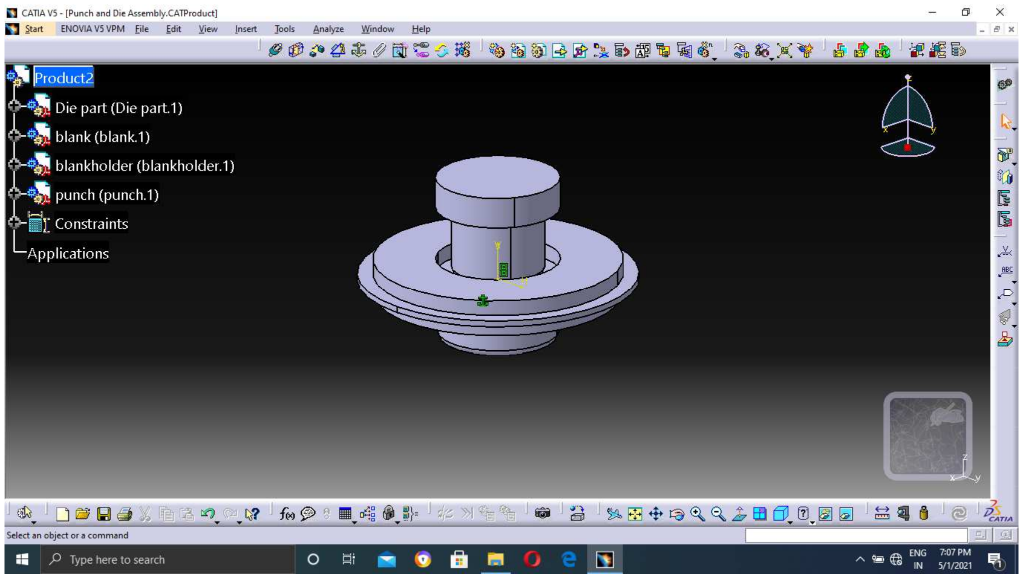


Fig 4.5 Deep drawing Assembly

4.4 SIMULATION

Analysis of the deep drawing operation is done in ANSYS.

4.4.1 ANSYS

ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

In general, a finite element solution may be broken into the following three stages. This is a general guideline that can be used for setting up any finite element analysis.

1. **Preprocessing: defining the problem**; the major steps in preprocessing are given below:
    - Define keypoints/lines/areas/volumes
    - Define element type and material/geometric properties

- Mesh lines/areas/volumes as required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axi-symmetric, 3D).

Solution: assigning loads, constraints and solving; here we specify the loads (point or pressure), contraints (translational and rotational) and finally solve the resulting set of equations.

2.**Postprocessing: further processing and viewing of the results;** in this stage one may wish to see:

- Lists of nodal displacements
- Element forces and moments
- Deflection plots
- Stress contour diagrams

ANSYS uses certain inputs and evaluates the product behavior to the physics that you are testing it in. It is a general purpose software used to simulate the interactions between various physics like dynamics, statics, fluids, electromagnetic, thermal, and vibrations. ANSYS typically creates the user an opportunity to create a virtual environment to simulate the tests or working conditions of the products before manufacturing the prototypes. This would certainly reduce the cost of producing prototypes and mainly the time. In this competitive world the accuracy and time are the most deciding factors for the company or the organization to sustain. ANSYS helps in increasing the accuracy and decreasing the time of outcome of the final product.

4.4.2 Advantages

- ANSYS can import all kinds of CAD geometries (3D and 2D) from different CAD software's and perform simulations, and also it has the capability of creating one effortlessly. ANSYS has inbuilt CAD developing software's like Design Modeler and Space Claim which makes the work flow even smoother.

- ANSYS has the capability of performing advanced engineering simulations accurately and realistic in nature by its variety of contact algorithms, time dependent simulations and non linear material models.
- ANSYS has the capability of integrating various physics into one platform and perform the analysis. Just like integrating a thermal analysis with structural and integrating fluid flow analysis with thermal and structural, etc.,
- ANSYS now has featured its development into a product called ANSYS AIM, which is capable of performing multi physics simulation. It is a single platform which can integrate all kinds of physics and perform simulations.
- ANSYS has its own customization tool called ACT which uses python as a background scripting language and used in creating customized user required features in it.
- ANSYS has the capability to optimize various features like the geometrical design, boundary conditions and analyse the behavior of the product under various criterion's.

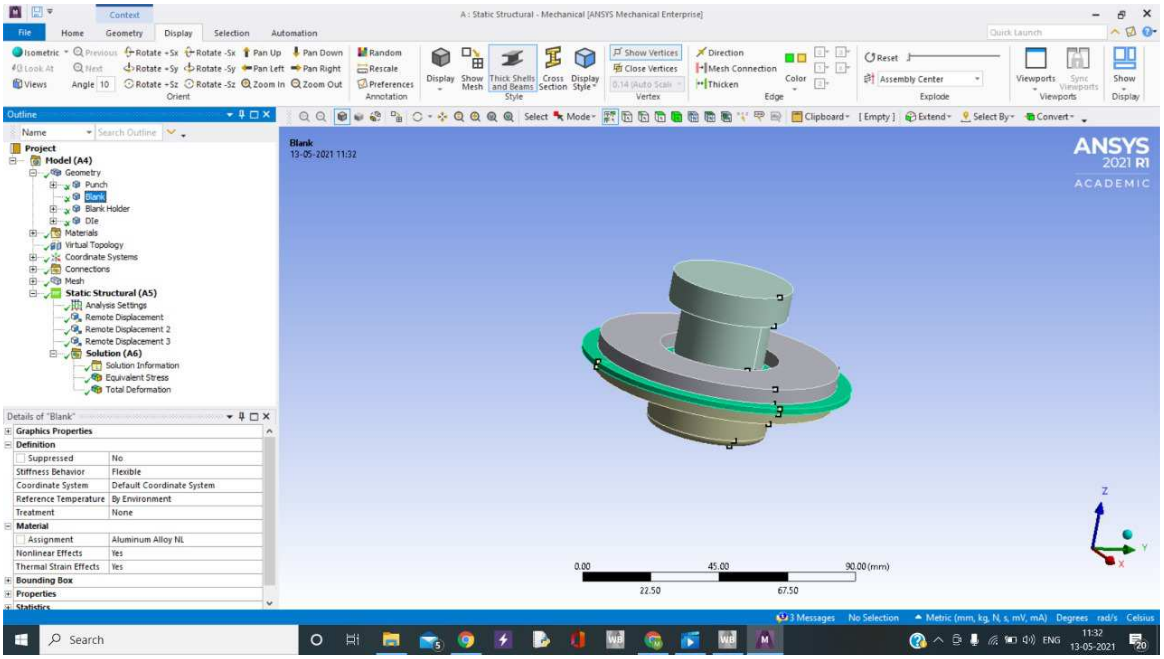


Fig 4.6 Imported assembly file in ANSYS

The above fig 4.6 shows the assembly file that is imported into the ansys workbench for the purpose of analysis and simulation.

Material is assigned to each of the parts.we have considered structural steel for punch,die and blank holder.

aluminium,copper and titanium for the blank

4.4.3 Material Properties

The material properties for various materials like structural steel,Aluminium alloy,copper alloy and titanium alloy has been mentionted in the following pictures.

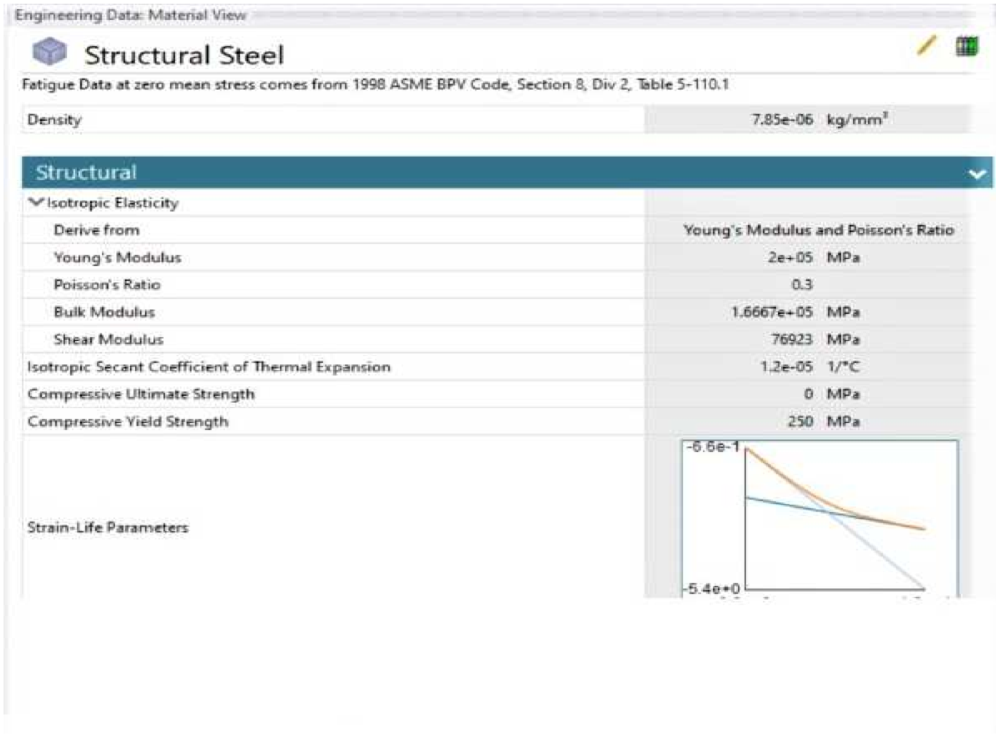


Fig 4.7 Properties of Structural steel

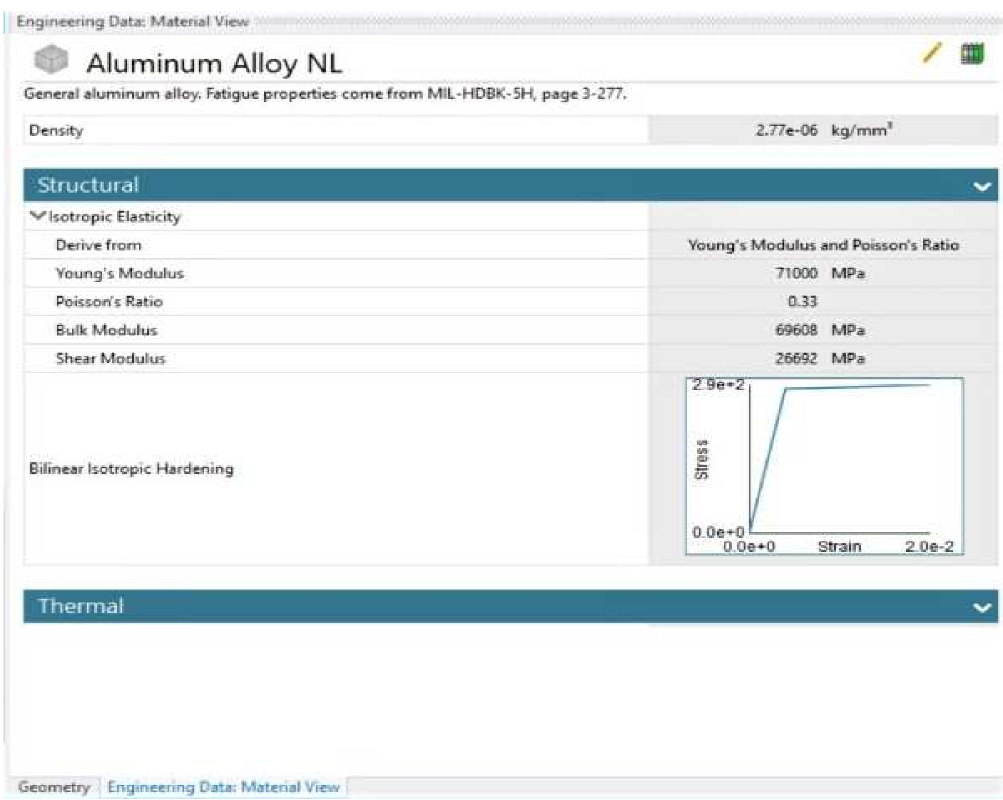


Fig 4.8 Properties of Aluminium alloy NL

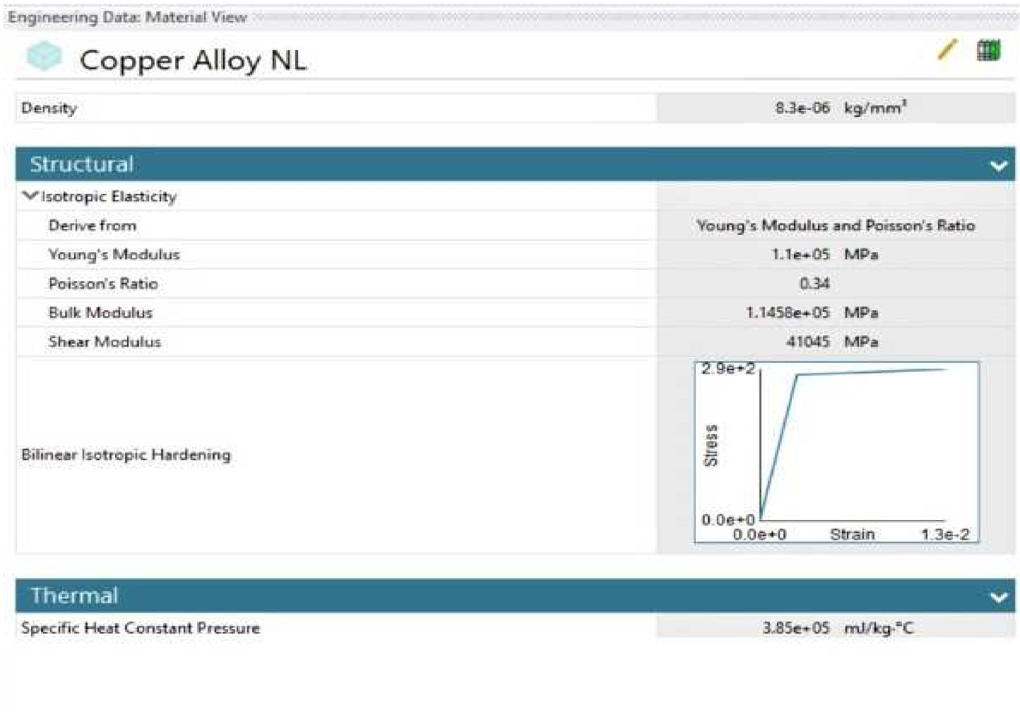


Fig 4.9 Properties of Copper alloy NL

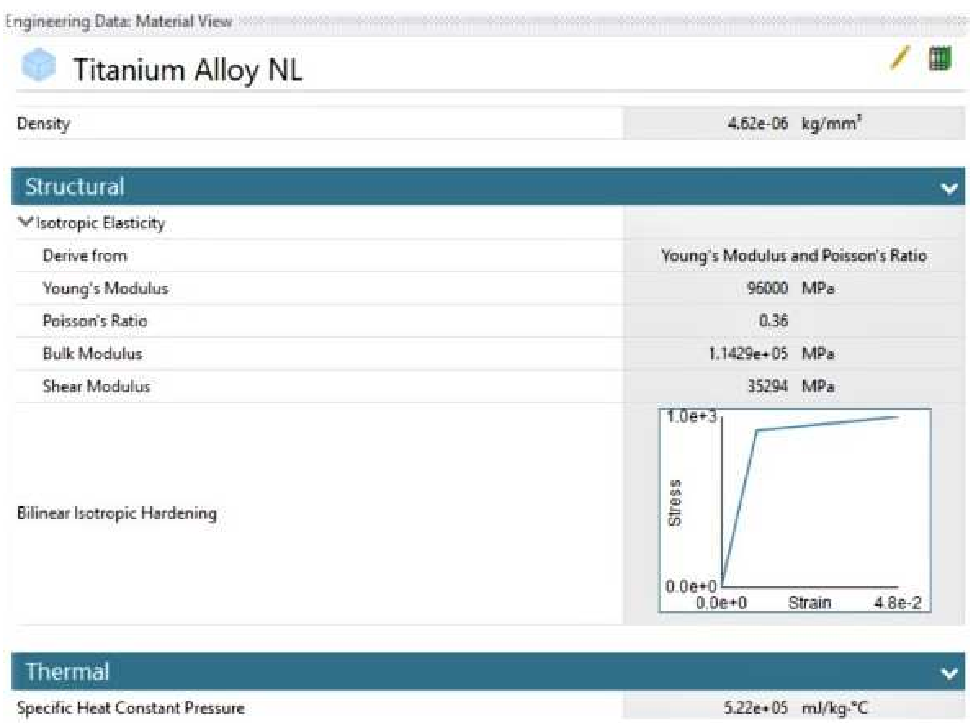


Fig 4.10 Properties of Titanium alloy NL

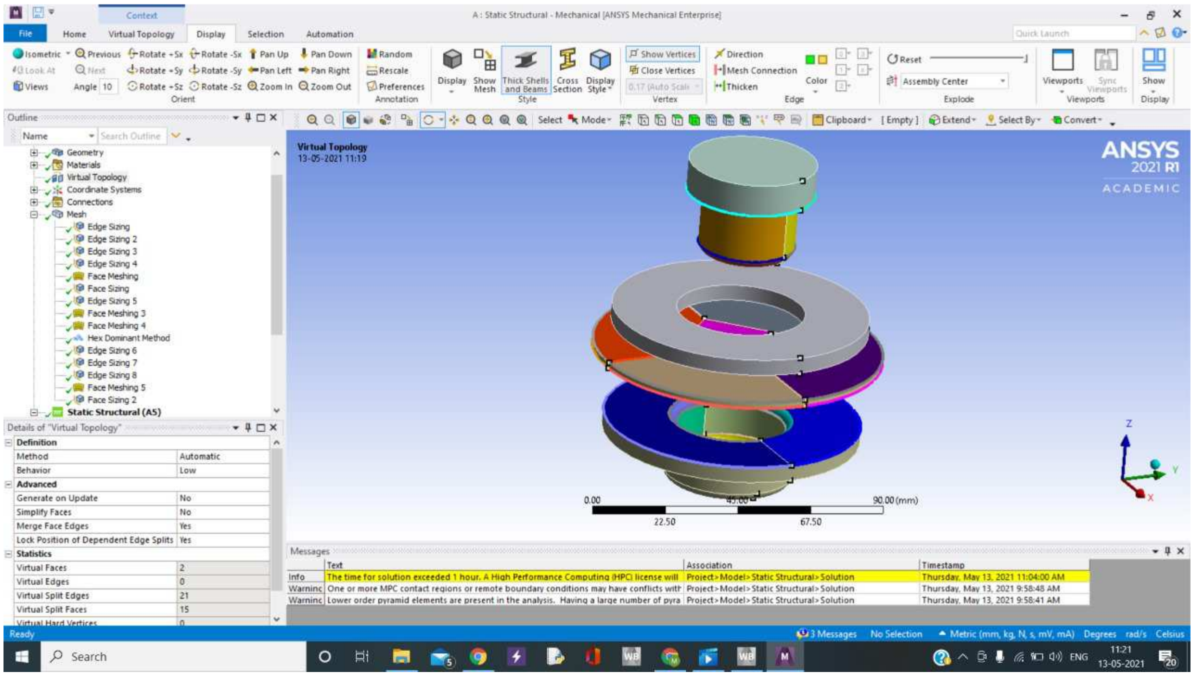


Fig 4.11 Virtual Topology

4.4.4 Virtual Topology

The topology of the model is its composition from faces, edges, and vertices. The Virtual Topology toolset allows you to manipulate this topology and create a simplified form for the purpose of meshing. This simplified form is different from the real model and is called virtual topology. The faces and edges that result from the manipulation are said to be virtual. Similarly, parts and part instances that contain virtual faces and edges are said to be virtual.

The Virtual Topology toolset allows you to remove small details by combining a small face with an adjacent face or by combining a small edge with an adjacent edge. The faces or edges to be combined can be specified directly, or you can choose the edges and vertices to ignore.The above Fig 4.11 shows the Virtual topology that is applied to the surfaces of the various parts of assembly

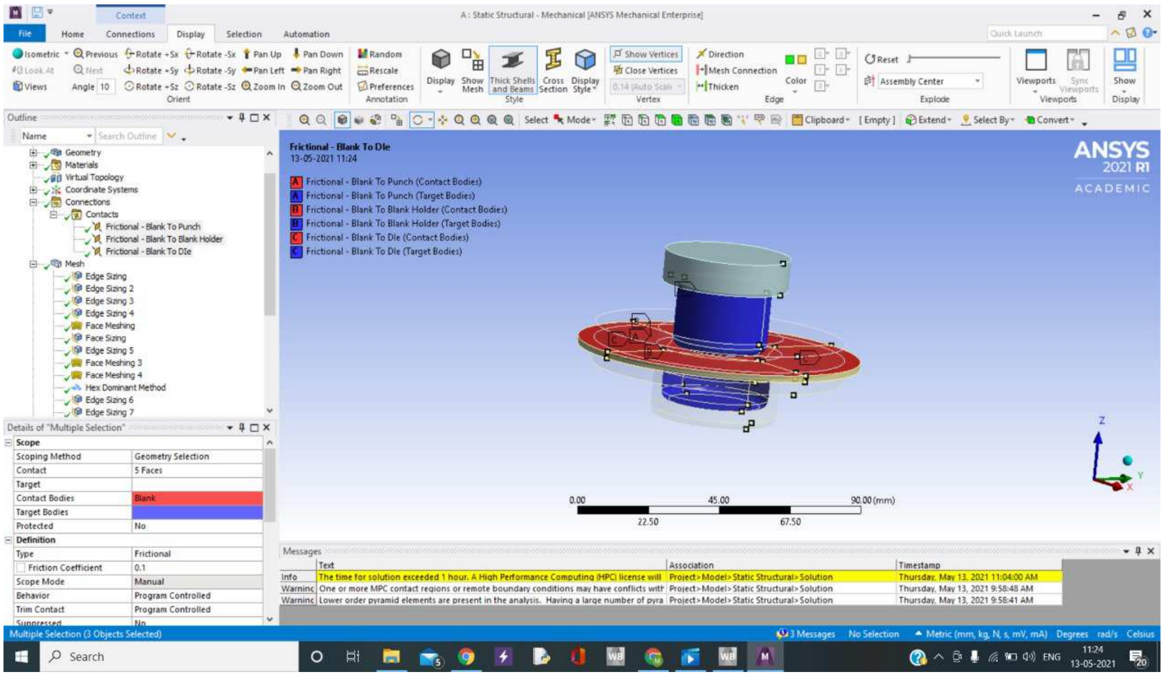


Fig 4.12 Connections

4.4.5 Connections

Here all the contacts are taken as frictional contacts with the friction coefficient as 0.1.

- The Blank is taken as the contact body and the target bodies are punch,blank holder and die respectively.

- The connections between the contact and target bodies are as follows:
  - ➢ Blank to Punch
  - ➢ Blank to Blank Holder
  - ➢ Blank to Die

The above Fig 4.12 shows the connections that are made in the deep drawing setup.

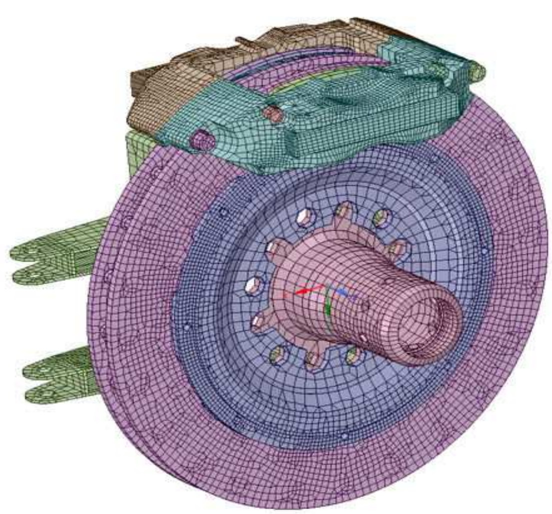
4.4.6 Meshing

ANSYS provides general purpose, high-performance, automated, intelligent meshing software that produces the most appropriate mesh for accurate, efficient multiphysics solutions from easy, automatic meshing to highly crafted mesh. Smart defaults are built into the software to make meshing a painless and intuitive task, delivering the required resolution to capture solution gradients properly for dependable results.

ANSYS meshing solutions range from easy, automated meshing to highly crafted meshing. Methods available cover the meshing spectrum of high-order to linear elements and fast tetrahedral and polyhedral to high-quality hexahedral and mosaic.

ANSYS meshing capabilities help reduce the amount of time and effort spent to get to accurate results. Since meshing typically consumes a significant portion of the time it takes to get simulation results, ANSYS helps by making better and more automated meshing tools.

Whether performing a structural, fluid or electromagnetic simulation, ANSYS can provide us with the most appropriate mesh for accurate and efficient solutions.The below image gives us a glimpse of ANSYS meshing



Meshing on punch:

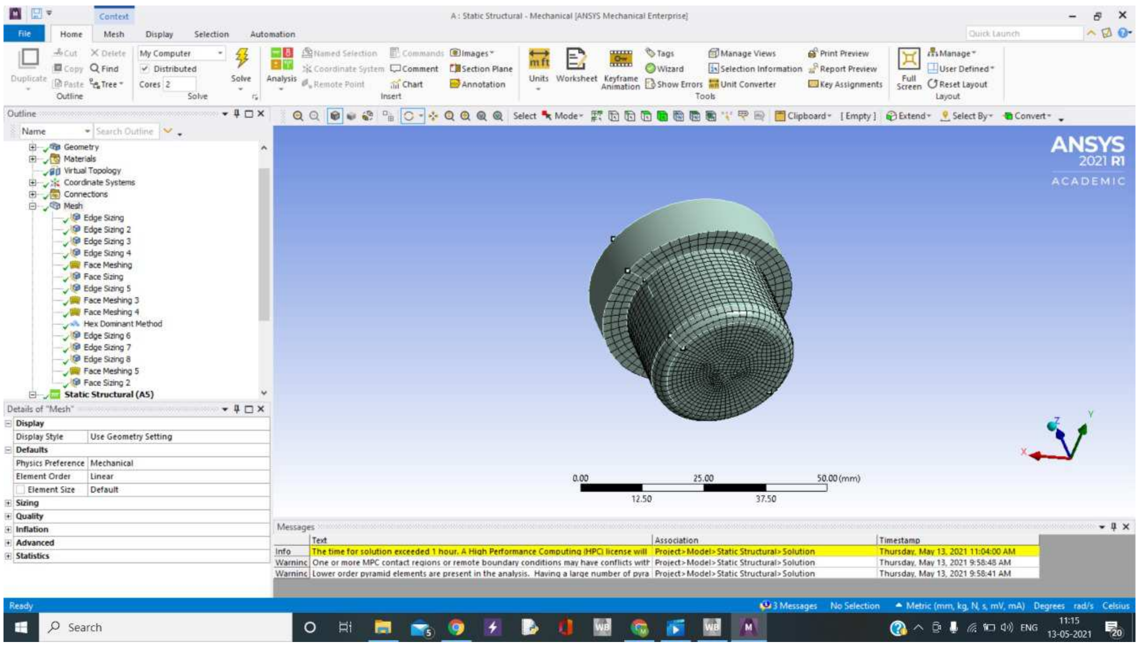


Fig 4.13 Meshing on punch

Edge sizing,face sizing and face meshing are the meshing techniques adopted for the meshing of punch.The above fig 4.13 shows the meshing on punch

- For the meshing to be more accurate certain number of divisions (3,30,15) are taken on various regions of punch in edge meshing.
- Face meshing is on the cylindrical surface of the punch.
- Face sizing is done on the punch bottom surface where the element size is taken as 1 mm
- Behaviour: Hard.

Meshing on Blank Holder

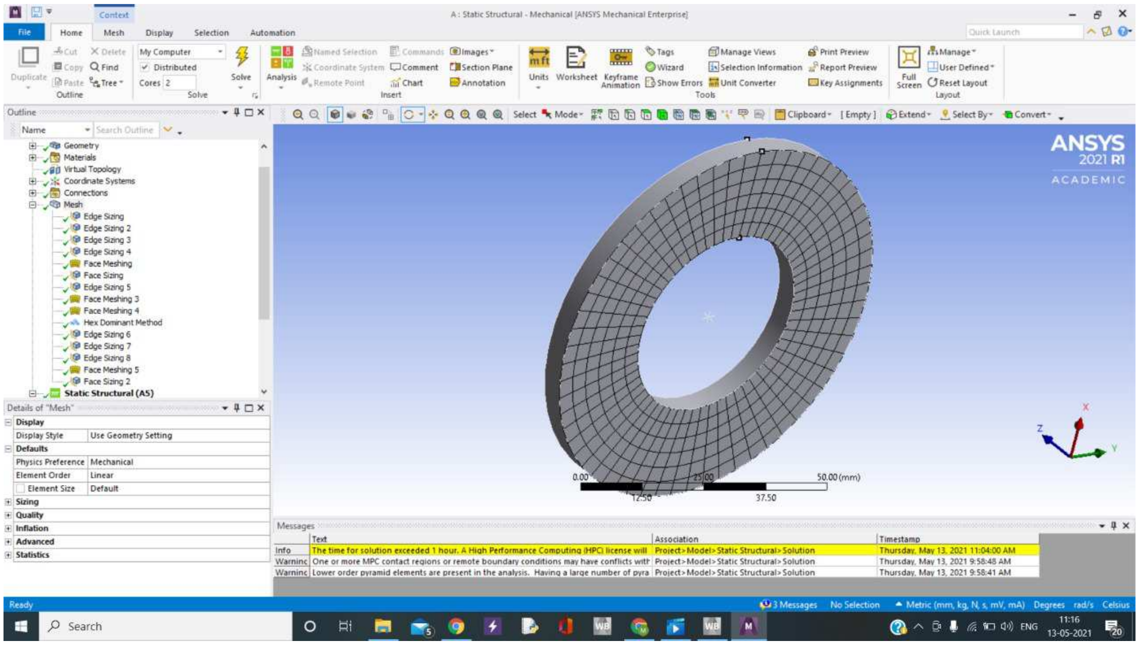


Fig 4.14 Meshing on blank holder

The above fig 4.14 shows the meshing on Blank holder.Edge sizing is adopted for the blank holder where the number of divisions are taken as 60.

Behaviour: Hard

Meshing on Blank

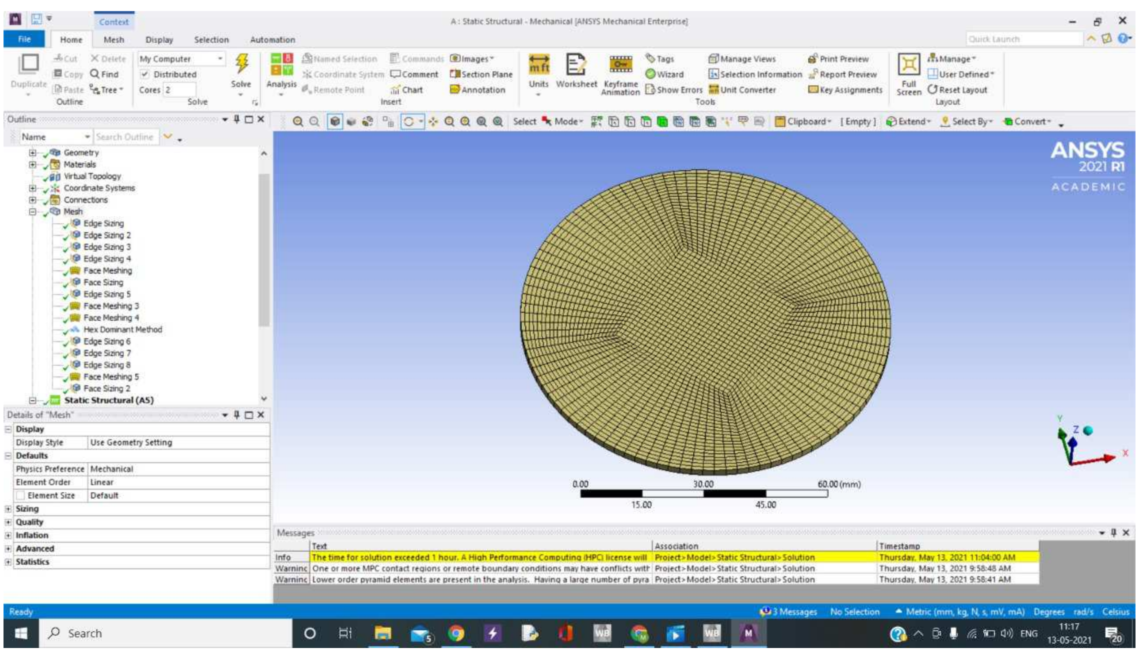


Fig 4.15 Meshing on Blank

The above fig 4.15 shows the meshing on blank

Edge sizing,face meshing and hex dominant methods are used for the meshing of blank.

The number of divisions are taken as 25 in edge sizing.

Hex dominant method is used for the meshing to be more accurate

Meshing on Die

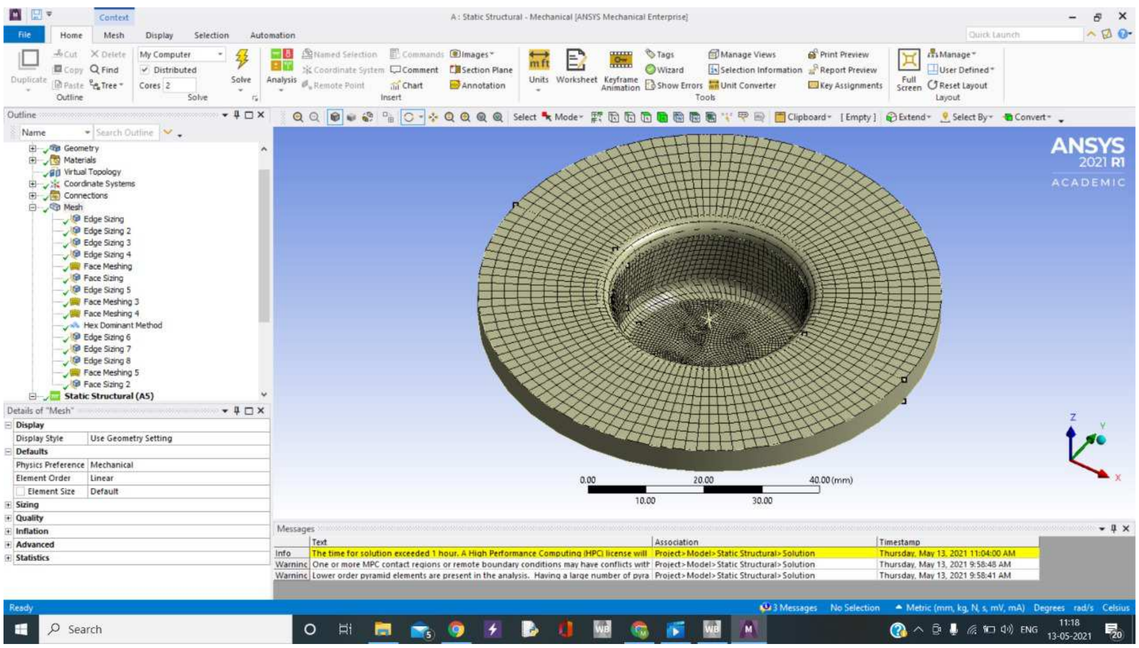


Fig 4.16 Meshing on die

The above fig 4.16 shows the meshing on Die

Edge sizing,face meshing and face sizing are adopted for the meshing of die.

- For the meshing to be more accurate certain number of divisions (3,9,60) are taken on various regions of punch in edge meshing.
- Face sizing is done for the inner bottom surface of die with element size as 0.5mm
- Face meshing is done on the die excluding the inner bottom surface of die.

Final Meshing of the assembly:

The combined meshing of the assembly is shown in the following figure.

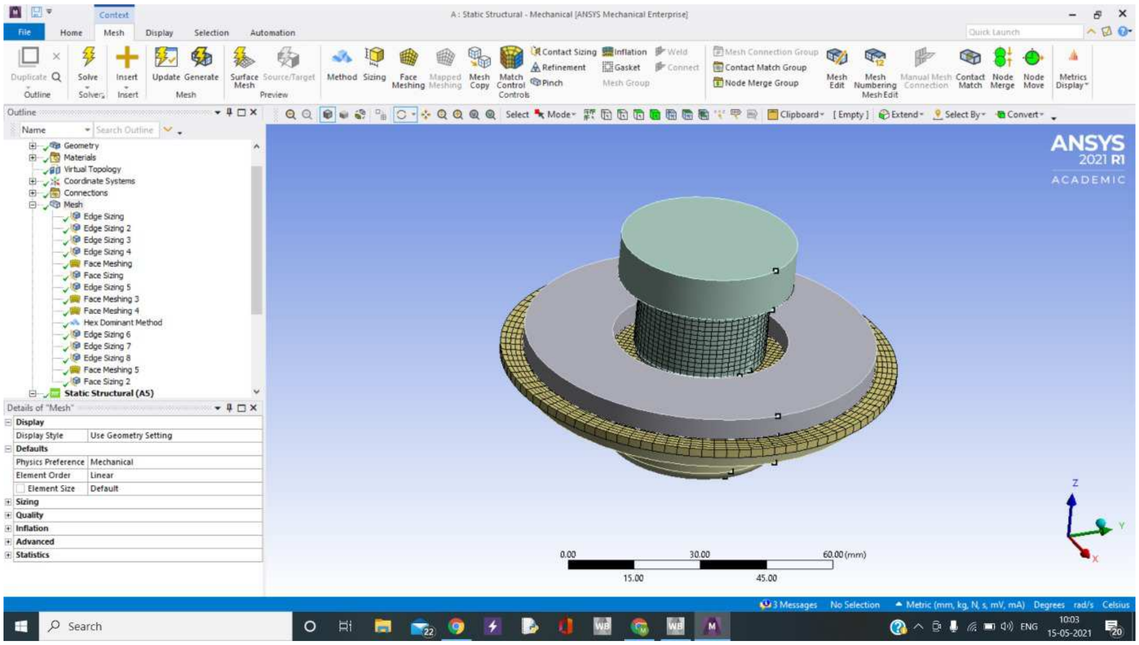


Fig 4.17 Meshing of final assembly

4.4.7 Remote Displacement:

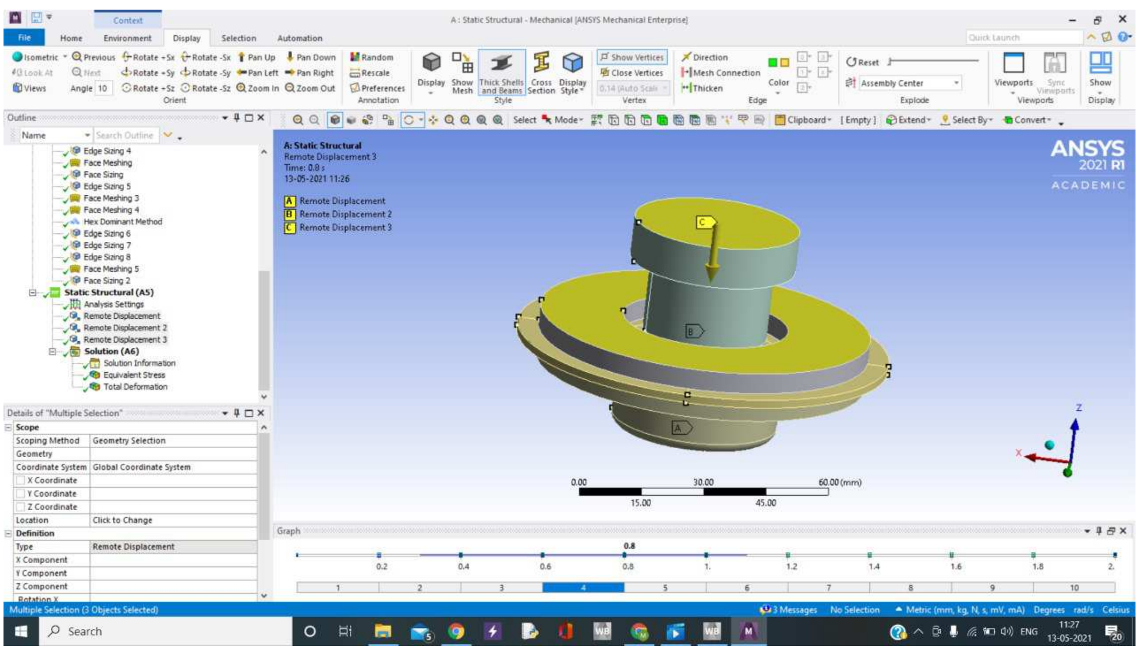


Fig 4.18 Remote displacement

The *Remote displacement* boundary condition is used to guide the displacement of a face or edge of a structure from a remote point. This provides several advantages compared to the classical displacement boundary condition such as:

- A deformation behavior can be added to the assigned entity.
- A rotation condition can be applied to an edge or a face of a structure.

- Remote Displacement A is applied to the DIE bottom surface where displacements in all directions are taken as zero i.e (x,y,z)=(0,0,0)
- Remote Displacement B is applied to the top surface of the BLANK HOLDER where displacements in all directions are taken as zero i.e (x,y,z)=(0,0,0)
- Remote Displacement Cis applied to the top surface of the PUNCH HEAD where displacements in x and y directions are taken as zero and 15mm in z direction i.e (x,y,z)=(0,0,15).Below fig 4.19 shows the tabular data of the displacements that are considered on punch.

Tabular Data

	Steps	Time [s]	X [mm]	Y [mm]	Z [mm]	RX [°]	RY [°]	RZ [°]
1	1	0.	0.	0.	0.	0.	0.	0.
2	1	0.2	= 0.	= 0.	= -1.5	= 0.	= 0.	= 0.
3	2	0.4	= 0.	= 0.	= -3.	= 0.	= 0.	= 0.
4	3	0.6	= 0.	= 0.	= -4.5	= 0.	= 0.	= 0.
5	4	0.8	= 0.	= 0.	= -6.	= 0.	= 0.	= 0.
6	5	1.	= 0.	= 0.	= -7.5	= 0.	= 0.	= 0.
7	6	1.2	= 0.	= 0.	= -9.	= 0.	= 0.	= 0.
8	7	1.4	= 0.	= 0.	= -10.5	= 0.	= 0.	= 0.
9	8	1.6	= 0.	= 0.	= -12.	= 0.	= 0.	= 0.
10	9	1.8	= 0.	= 0.	= -13.5	= 0.	= 0.	= 0.
11	10	2.	= 0.	= 0.	-15.	= 0.	= 0.	= 0.
*								

Fig 4.19 Tabular data

After considering all of the above conditions the project is ready to solve.

- In analysis settings under the solution part we have considered the total deformation,stress and strain.

After solving the blank is drawn into the desired cup.

The below fig 4.20 shows the cup that is drawn and it provides the necessary solutions.

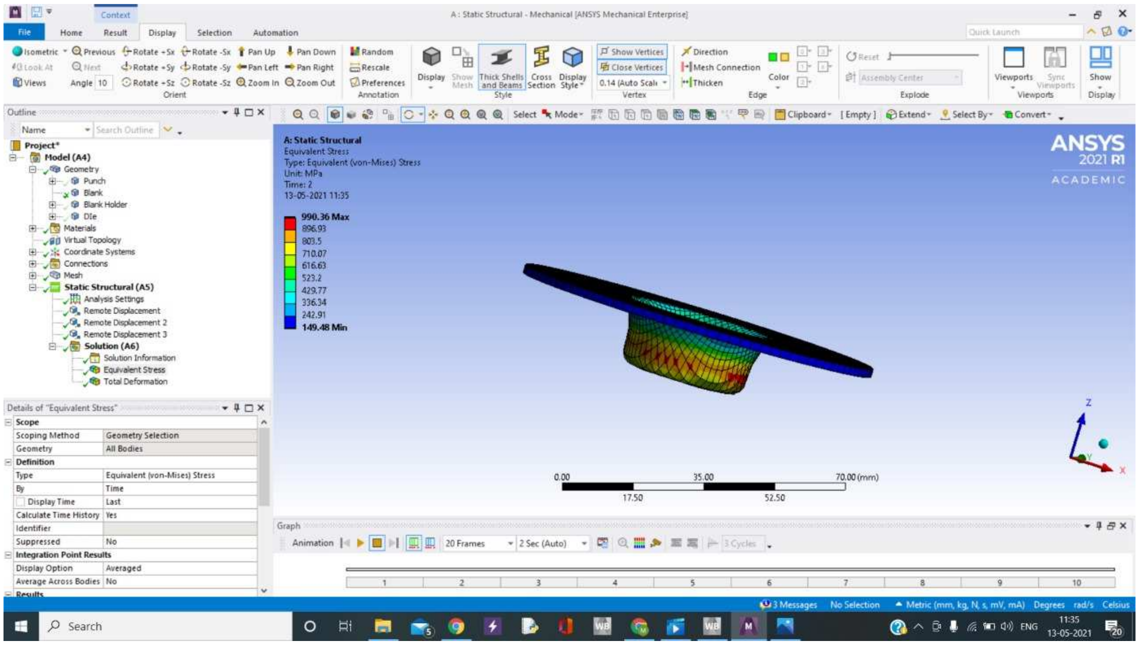
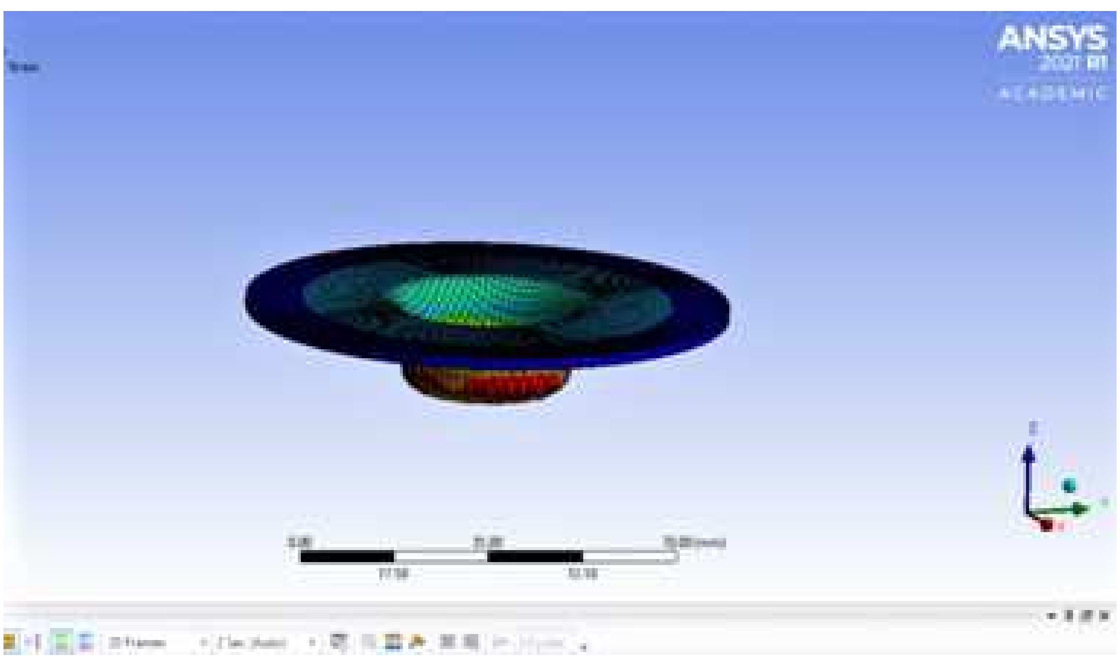


Fig 4.20 cup drawn

In our project we have considered various materials like Aluminium,Copper,Titanium for the blank.

We have obtained the solution for each of the material and the results are depicted as follows:



4.4.8 SOLUTIONS OBTAINED

1.ALUMINIUM:

SOLUTION INFORMATION

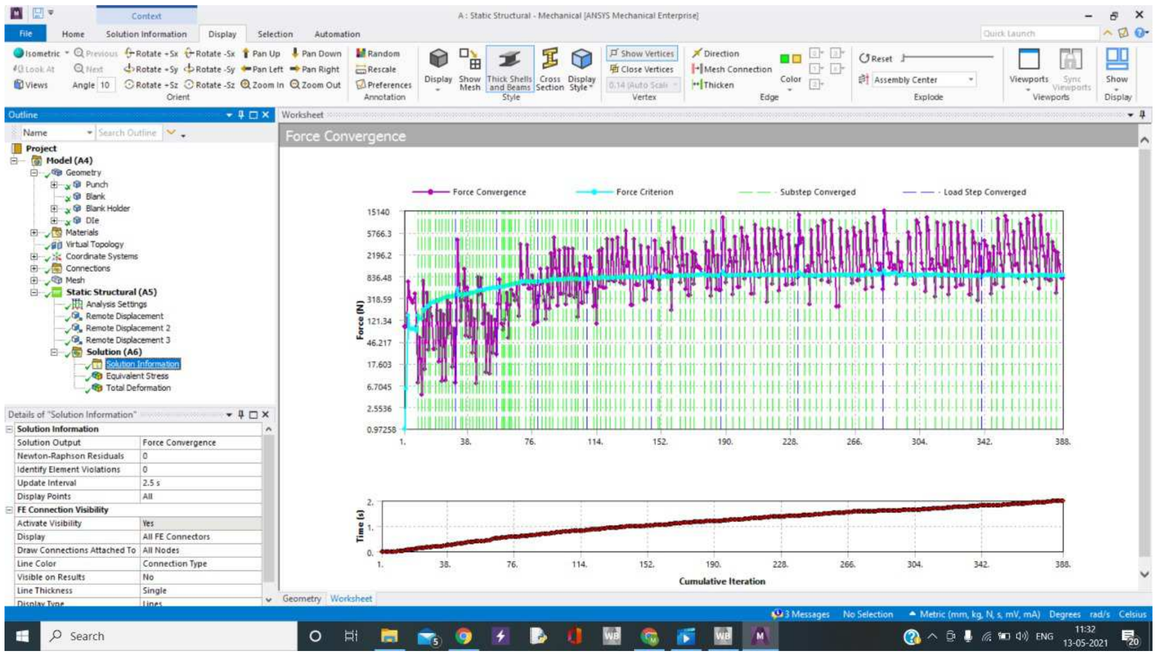


Fig 4.21 Force convergence in Al

The above fig 4.21 provides information about the force convergence in the solution information.

The following are the results for the stresses,strains and total deformation that are generated in the various regions of cup i.e flane of the cup,vertical wall and punch bottom.

Stress:

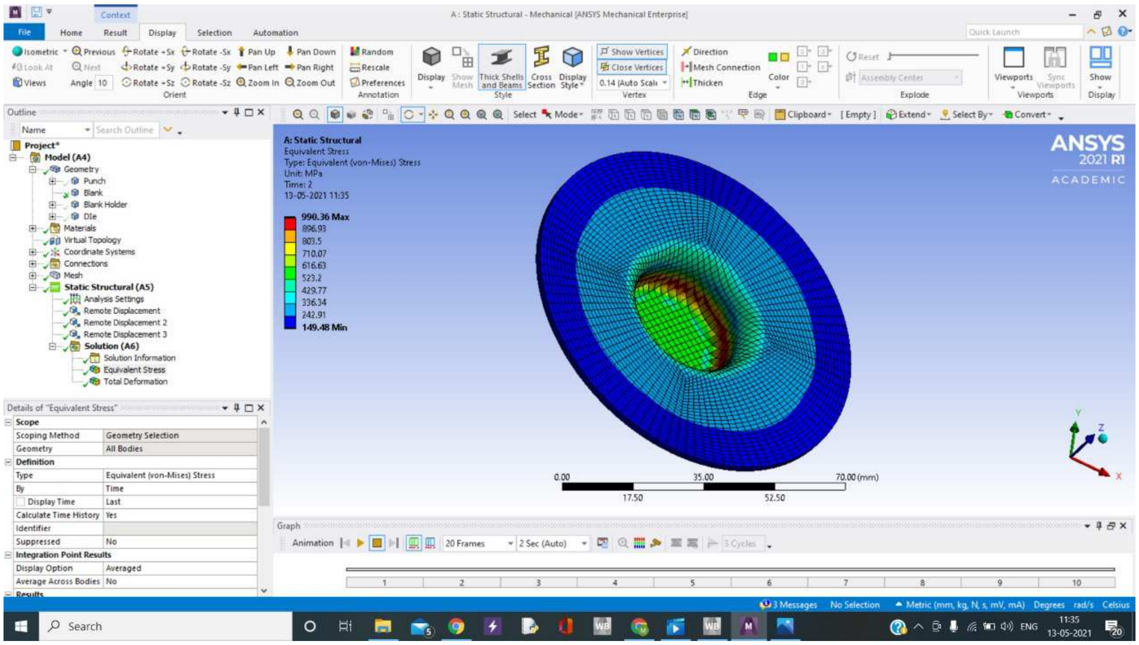


Fig 4.22 Stresses generated in Al cup

The Von mises stress is indicated in the above fig 4.22.The **maximum** and **minimum** stresses that are generated in the cup are **990.36 MPa** and **149.48 MPa** respectively.

Total deformation

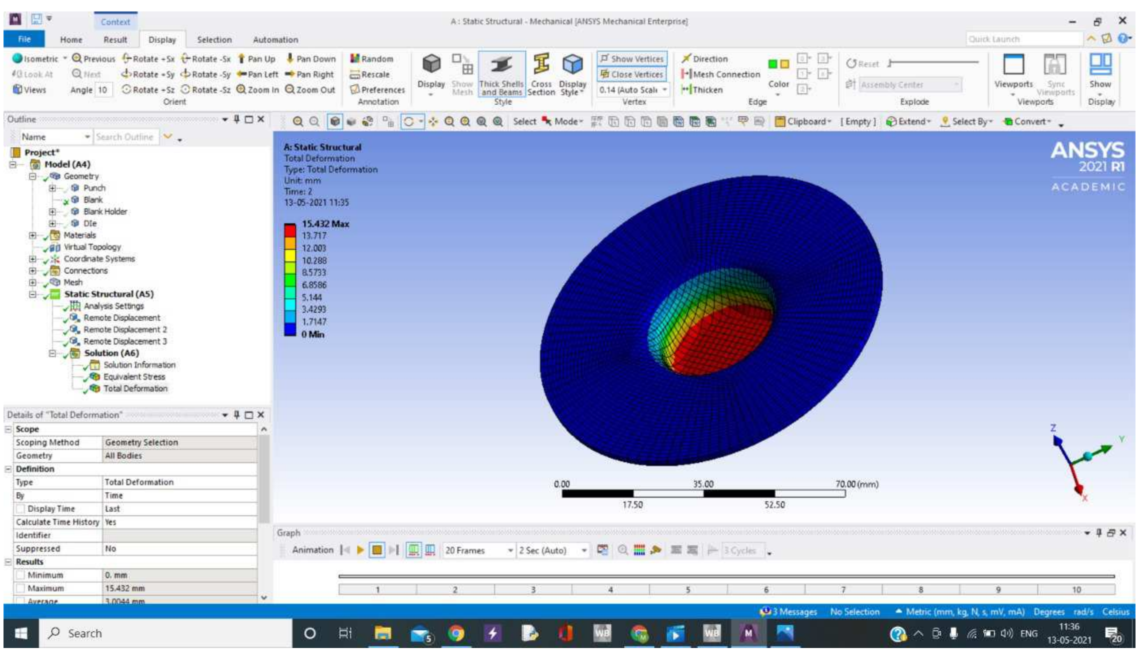


Fig 4.23 Total deformation in Al

The total deformation in the cup is shown in the fig 4.23.The **maximum** deformation in the cup is recorded as **15.432mm** and the **minimum** deformation is recorded as **0mm**.

Strain

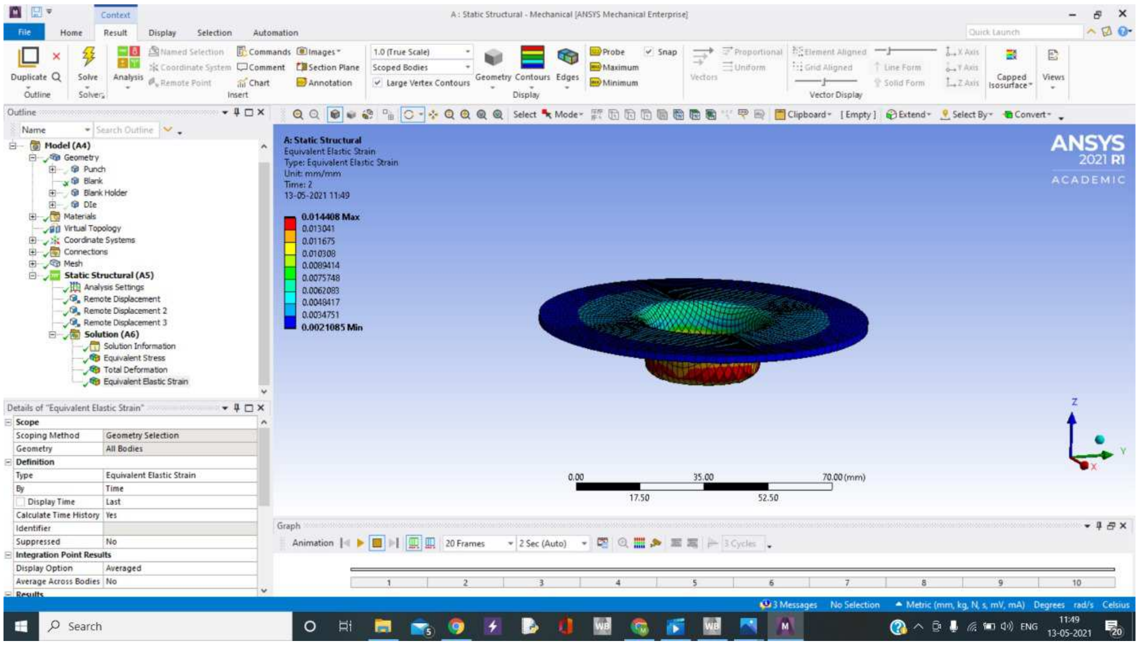
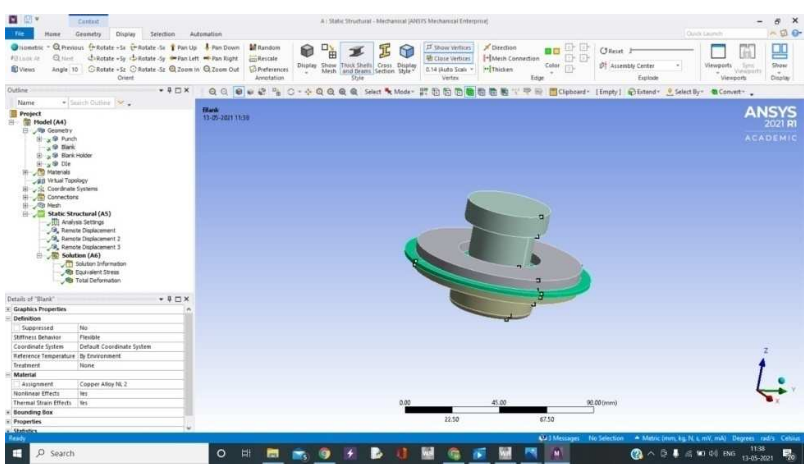


Fig 4.24 Strain in Al

The strain in the Al is shown in the above fig 4.24.The **maximum** and **minimum** strain in the cup are recorded as **0.014408** and **0.0021085.**

COPPER



Solution Information

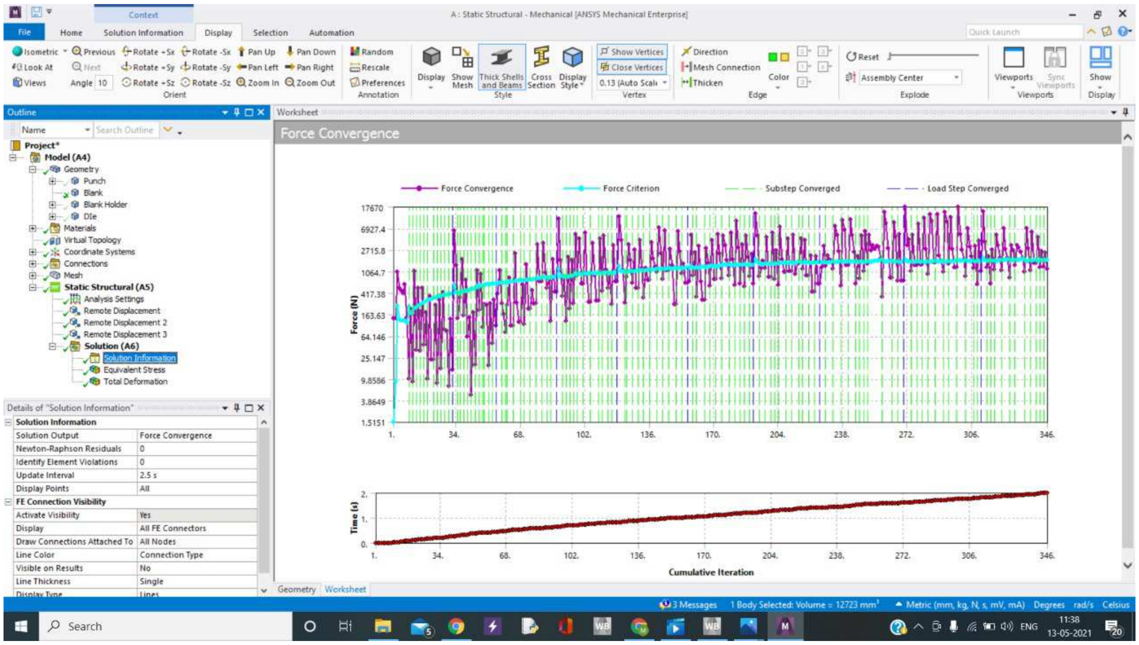


Fig 4.25 Force convergence in Cu

The above fig 4.25 provides information about the force convergence in the solution information

Stress

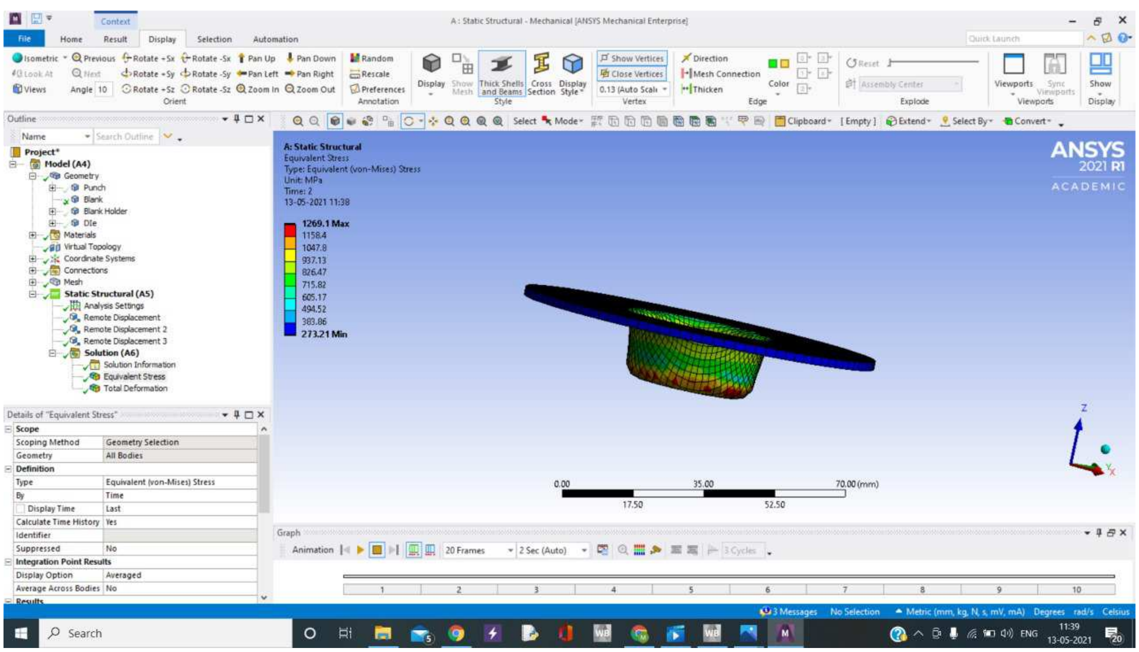


Fig 4.26 Stresses generated in Cu cup

The Von mises stress is indicated in the above fig 4.26.The **maximum** and **minimum** stresses that are generated in the cup are **1269.1 MPa** and **273.21 MPa** respectively.

Total deformation

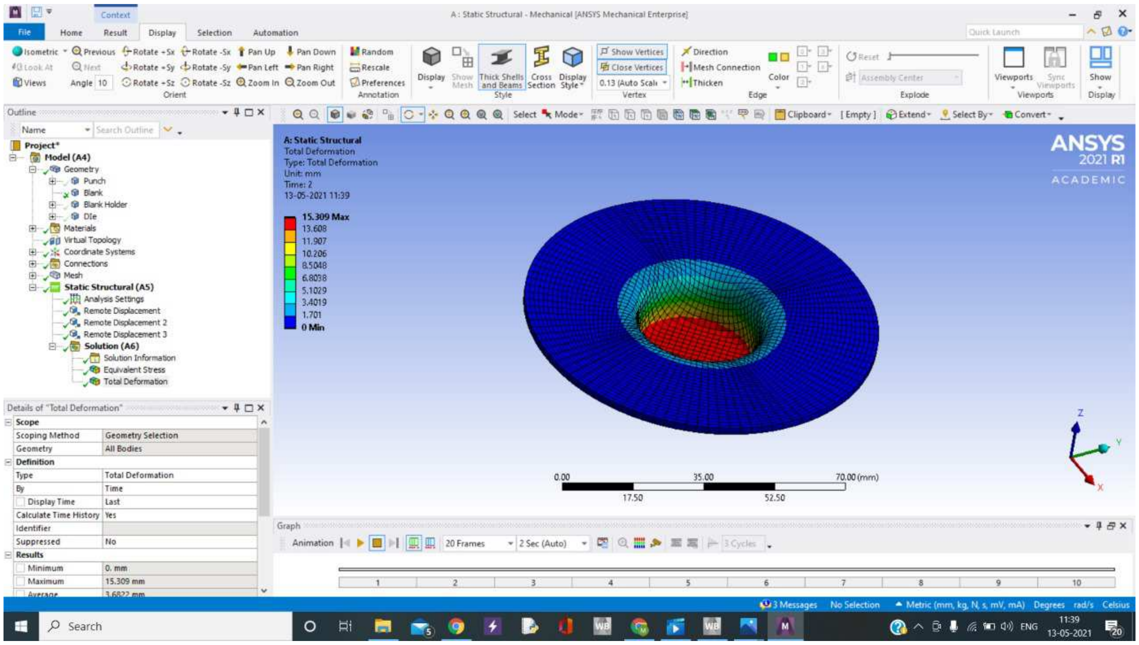


Fig 4.27 Total deformation in Cu

The total deformation in the cup is shown in the fig 4.27.The **maximum** deformation in the cup is recorded as **15.309 mm** and the **minimum** deformation is recorded as **0mm.**

Strain

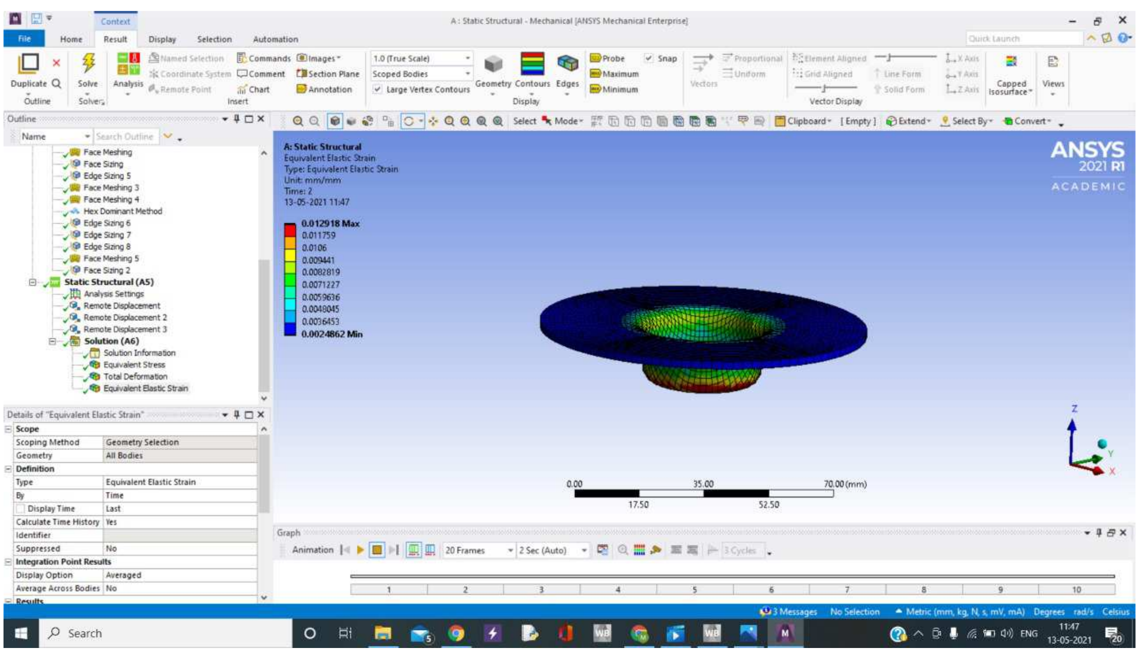


Fig 4.28 Strain in Cu

The maximum and minimum strain in the cup are recorded as **0.012918** and **0.002462**

3.TITANIUM

Solution information

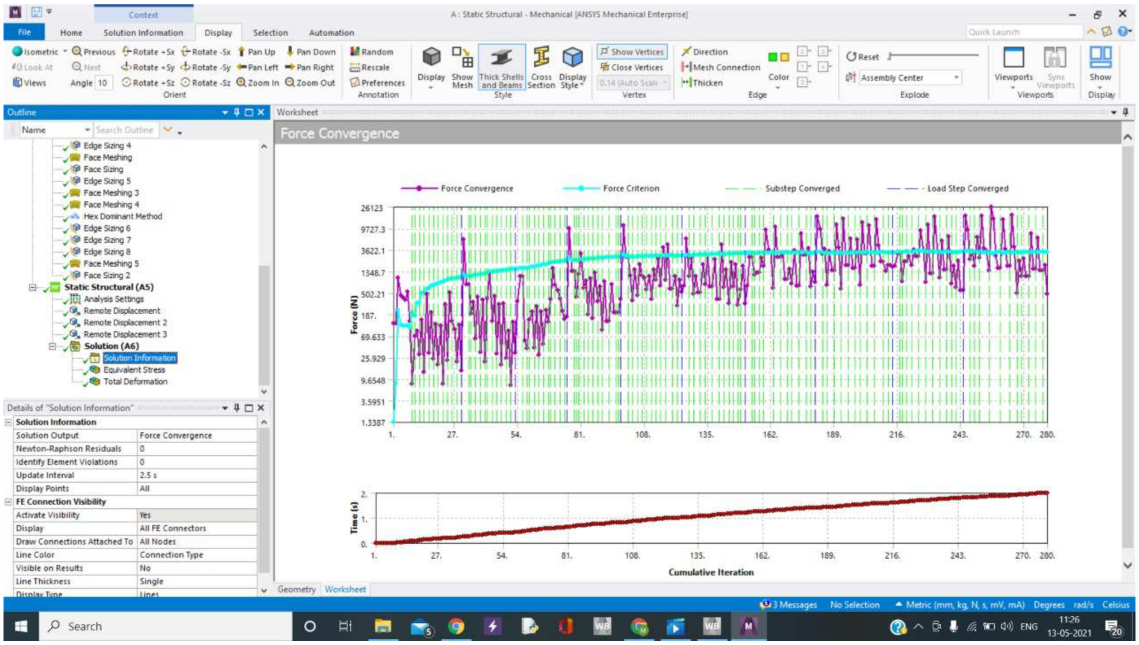


Fig 4.29 Force convergence in Ti

The above fig 4.29 provides information about the force convergence in the solution information.

Stress

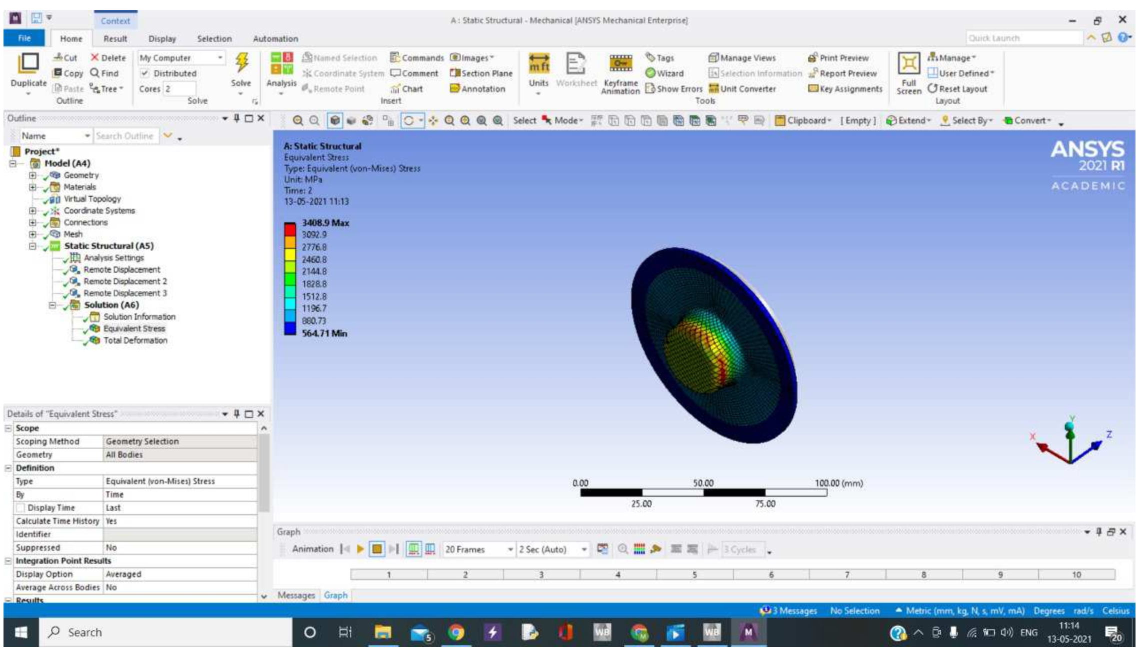


Fig 4.30 Stresses generated in Ti cup

The Von mises stress is indicated in the above fig 4.30.The maximum and minimum stresses that are generated in the cup are **3408.9 MPa** and **564.71 MPa** respectively

Total Deformation

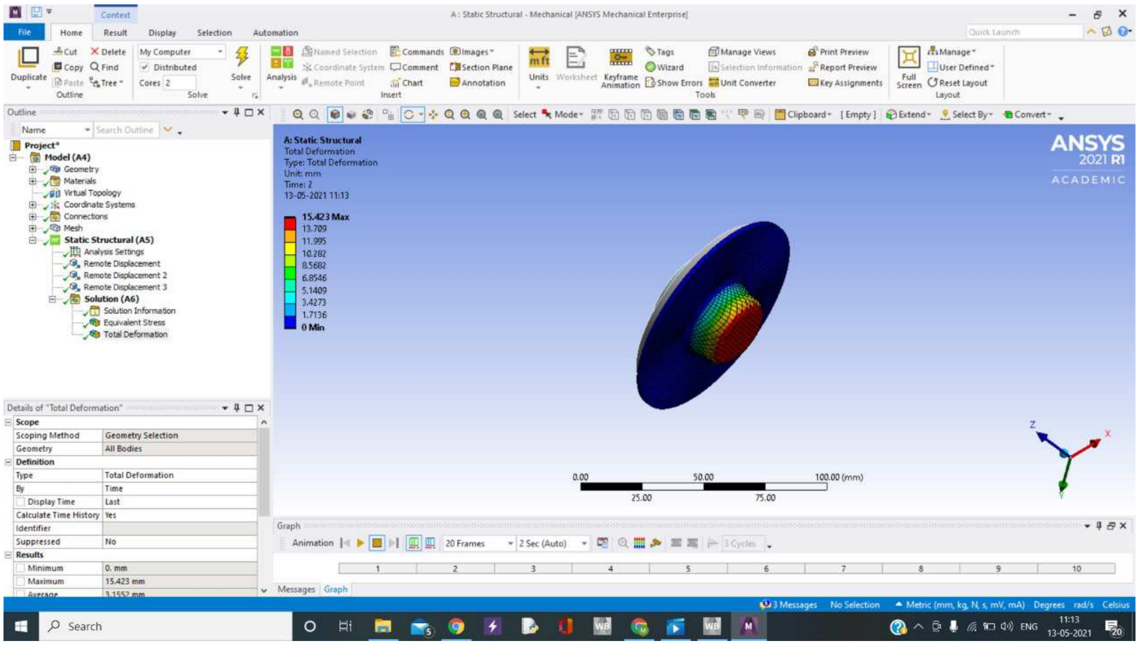


Fig 4.31 Total deformation in Ti

The total deformation in the cup is shown in the fig 4.31.The maximum deformation in the cup is recorded as **15.423** mm and the minimum deformation is recorded as **0mm**

Strain

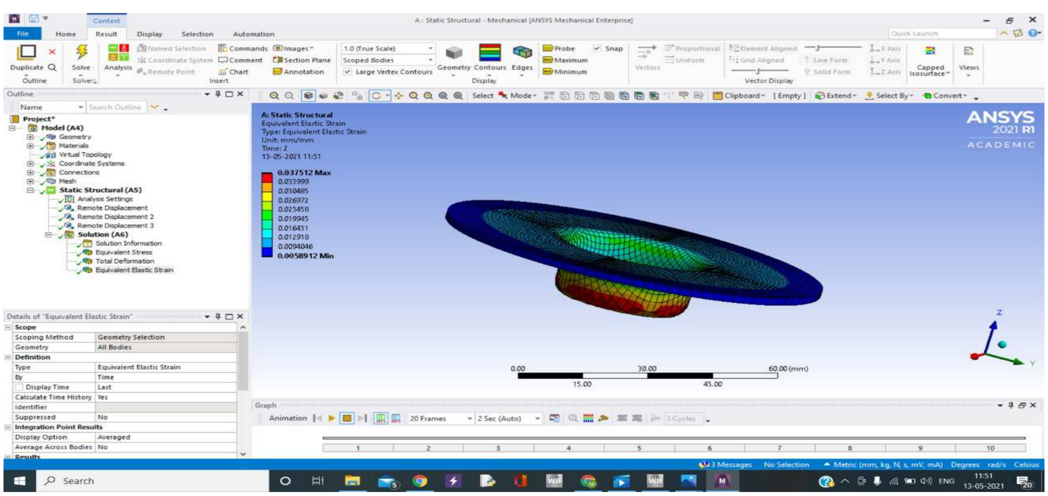


Fig 4.32 Strain in Ti

The strain in the Ti is shown in the above fig 4.32. The maximum and minimum strain in the cup are recorded as 0.037512 and 0.0058912.

CHAPTER- V

CONCLUSIONS

From the analysis carried out, the following results are obtained as presented in Table 5.1

Table 5.1 Comparision of results

S.NO	**MATERIAL**	**STRESS** (in MPa)	**STRAIN**	**TOTAL DEFORMATION** (in mm)
1.	Aluminium	990.36	0.014408	15.432
2.	Copper	1296.1	0.012918	15.309
3.	Titanium	3408.9	0.037512	15.423

The above table compares the **maximum** values of stress, strain and deformation of different materials.

- We can observe that the maximum stress and strain are generated in TITANIUM alloy.
- Where as the maximum total deformation is generated in ALUMINIUM alloy.

By considering the various stress patterns in the cup drawn, we came to a conclusion that the

- Flange region has the minimum stress
- Punch bottom region has the maximum stress

REFERENCES

[1] Mark Colgan, John Monaghan, “Deep Drawing process: analysis and experiment”,Journal of Materials Processing Technology,132, 2003, 35 41.

[2] S. RAJU, G. GANESAN, R. KARTHIKEYAN, “Influence of variables in deep drawing of AA 6061 sheet” , Trans. Non-ferrous society of china 20(2010) 1856-1862. |

[3] Kopanathigowtham, K.V.N.S. Srikanth&k.L.N. Murty, “Simulation of the effect of die radius on deep drawing process, International Journal of Applied Research in Mechanical Engineering ISSN: 2231 –5950, Volume-2, Issue-1, 2012.

[4] R. Padmanabhan, M.C. Oliveira, J.L. Alves, L.F. Menezes, “Inuence of process parameters on the deep drawing of stainless steel”, Finite Elements in Analysis and Design 43 (2007) 1062 – 1067.

[5] R. Venkat Reddy, Dr T.A. Janardhan Reddy, Dr. G.C.M. Reddy, “Effect of Various Parameters on the Wrinkling In Deep Drawing Cylindrical Cups”, International Journal of Engineering Trends and Technology- Volume3 Issue1- 2012.

[6] Y. Marumo, H. Saiki, L Ruan, “Effect of sheet thickness on Deep Drawing of Metal Foils”, Journal of Achievements in Materials and Manufacturing Engineering VOLUME 20 ISSUES 1-2 January-February 2007, 479-482. |

[7] A. FallahiArezodar and A. Eghbali, “Evaluating the Parameters Affecting the Distribution of Thickness in Cup Deep drawing of ST14 Sheet” , Journal of Advanced Science and Engineering Research Vol 2, No 3 September (2012) 223-231.

[8] A. R. Joshi, K. D. Kothari, Dr. R. L. Jhala, “Effects Of Different Parameters On Deep Drawing Process”; International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, March – 2013 ISSN: 2278-0181.

[9] Young Hoon Moon, Yong Kee Kang, Jin Wook Park, Sung Rak Gong, "Deep Drawing With Internal Air-Pressing to Increase The Limit Drawing Ratio of Aluminum Sheet", KSME International Journal; VoL 15 No.4, pp. 459- 464, 2001

[10]Saniee, F.F., Montazeran, M.H., A comparative estimation of the forming load in the deep drawing process, Journals of Materials Processing's Technology 140 (2003) 555-561.

[11]Verma, R., Chandra, S., An improved model for predicting limiting drawing ratio, Journals of Materials Processing Technology, (2005) 1-07

[12]Alexander J.M., An Appraisal of Theory of Deep Drawing, Metallurgical Reviews, Vol. 5, Vol. 19 (1960) 349-411.

[13]Li Y Q, Cui, Z S, Ruan X Y, Zhang D J 2006 CAE-based six sigma robust optimization for deep-drawing sheet metal process International Journal of Advanced Manufacturing Technology, 30, pp. 631–637.

[14]P.VR.RavindraReddy,G.ChandraMohanReddy,TA.JanardhanReddy,"Studie s On The Effect Of Blank Holding Force And The Die Corner Radius On The Limit Strains in the deep drawing process",Indian Journal Of EngineringAnd Material Science,Vol.19,February2012,p.p 24-30.

[15]N. C. Mehta, Viral V. Shiyani, Jemish R. Nasit ," Metal Forming Analysis", International Journal of Emerging Technology and Advanced Engineering, Volume 3, 2013.

[16]Brabie G, Nanu N, Radu ME. The influence of the punch shape on the residual stresses distribution and springback in the case of conical drawn parts. In: NEWTECH 2009, GALATI, Romania, ISSN 1221-4566; 2009. p. 87–90.

[17]Chandra Pal Singh, Geeta.Agnihotri Study of Deep Drawing Process Parameters International Journal of Scientific and Research Publications, Volume 5, Issue 2, February 2015 1 ISSN 2250-3153

[18]Adnan I. O. Zaid.Effect of Different Lubricants on Deep Drawing of Galvanized Steel International Journal of Scientific & Engineering Research, Volume 8, Issue 1, January-2017 1584 ISSN 2229-5518

[19]Najmeddin Arab, Abotaleb Javadimanesh, "Theoretical and Experimental Analysis of Deep Drawing Cylindrical Cup"; Journal of Minerals and Materials Characterization and Engineering, 2013, 1, 336-342

[20]Sanjay K. Ansodariya Bharat J. Kapadiya "Experimental and Simulation Progress on Deep drawing Process"; IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 05, 2016 | ISSN (online): 2321-0613

[21]Aniruddh Shukla , Dr Dharmendra Tyagi "Drawing Analysis of Aluminum Alloy Aa1200 Sheet Metal" Journal of Recent Activities in Production Volume 4 Issue 1

[22]Jenn-TerngGau,SujithTeegala, KunMin Huang,d, Tun-Jen Hsiao, BorTsuen Lin; 2013; Using micro deep drawing with ironing stages to form stainless steel304 micro cups; Journal of Manufacturing Processes

[23]H. Gharib,A.S. Wifi,M. Younan, A. Nassef; 2006;Optimization of the blank holder force in cup drawing; Journal of Achievements in Materials and Manufacturing Engineering;

[24] Pradipkumar Patil, K.H.Inamdar "Study of effect of various parameters on Thinning tendency in Deep Drawing using Simulation" JETIR1606016 Journal of Emerging Technologies and Innovative Research (JETIR)

[25]Ravindra K.Saxena, P.M. Dixit; 2011;Numerical analysis of damage for prediction of fracture initiation in deep drawing; Finite Elements in Analysis and Design

[26]Suresh Kurra, Srinivasa Prakash Regalla; 2014;Experimental and numerical studies on formability of extra-deep drawing steel in incremental sheet metal forming; journal of material research and technology

[27]V.Malikova,,R.Ossenbrink,B.Viehweger,V. Michailov; 2012; Experimental study of the change of stiffness properties during deep drawing of structured sheet metal; Journal of Materials Processing Technology

[28]Patil P.M.Bajaj P. S.,2013,Tool design of cylindrical cup for multi-stage drawing process,International Journal of Latest Trends in Engineering and Technology,Vol. 3, No. 2, pp. 100-106.

[29]Magar, S.M., Ghanegaonkar, P.M., Vikhe, G.J., Investigations of Deep drawing of cylindrical components, Lambert Academic Publishing, Edition 1, 2011

[30]Shishir Anwekar, Abhishek Jain "Determination of Strain Distribution in Single Stage Deep Drawing Process by Finite Element Simulation" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684 Volume 4, Issue 5 (Nov. - Dec. 2012), PP 15-22