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Design and Analysis of Deep Drawing for a Utility Cup

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Abstarct:- Sheet metal forming is one of the widely used processes in the automobile and aerospace industries. This project represents the analysis of the sheet metal forming process mainly deep drawing. ANSYS simulation is being executed to achieve the results of extreme behavior of the product. The main objective of this project is to do the static analysis on the deep drawing operation for a utility cup. The theoretical value will give the dimension of die and punch. From the values obtained, a CAD model is generated in CATIA, making use of the dimensions. This assembly is then converted into the .stp format to import that file into ANSYS. From the simulation, deformation can be obtained; that force required for developing the part.

Keywords:- *Ansys, Catia, Deep Drawing, Metal Forming.*

I. INTRODUCTION

Deep drawing is a manufacturing process used to form sheet metal into a desired shape using a punch and die. It is commonly used to create cylindrical or box-shaped components with a depth greater than their diameter.

Deep drawing is a method employed in sheet metal work which does not use seam and its depth is more than its radius. It is a combination of process whereby a sheet metal blank is radially pulled in to a forming die by mechanical action of a punch. The process is referred to as deep drawing when the height of the drawn component is larger than its diameter. The accurate size reaches the limit in the deep drawing press. The total drawing load comprises of the ideal forming load and a further component which is used to counterbalance the effects of friction and bending moments. Many industries such as automotive, airplane and even medical devices make use for deep drawing process to manufacture parts with straight edges and curves. It provides a cheaper option compared to other methods of metal forming like machining and casting. Deep drawing is a comprehensive technique and can be applied to manufacture various categories of the components, basic to intricate.

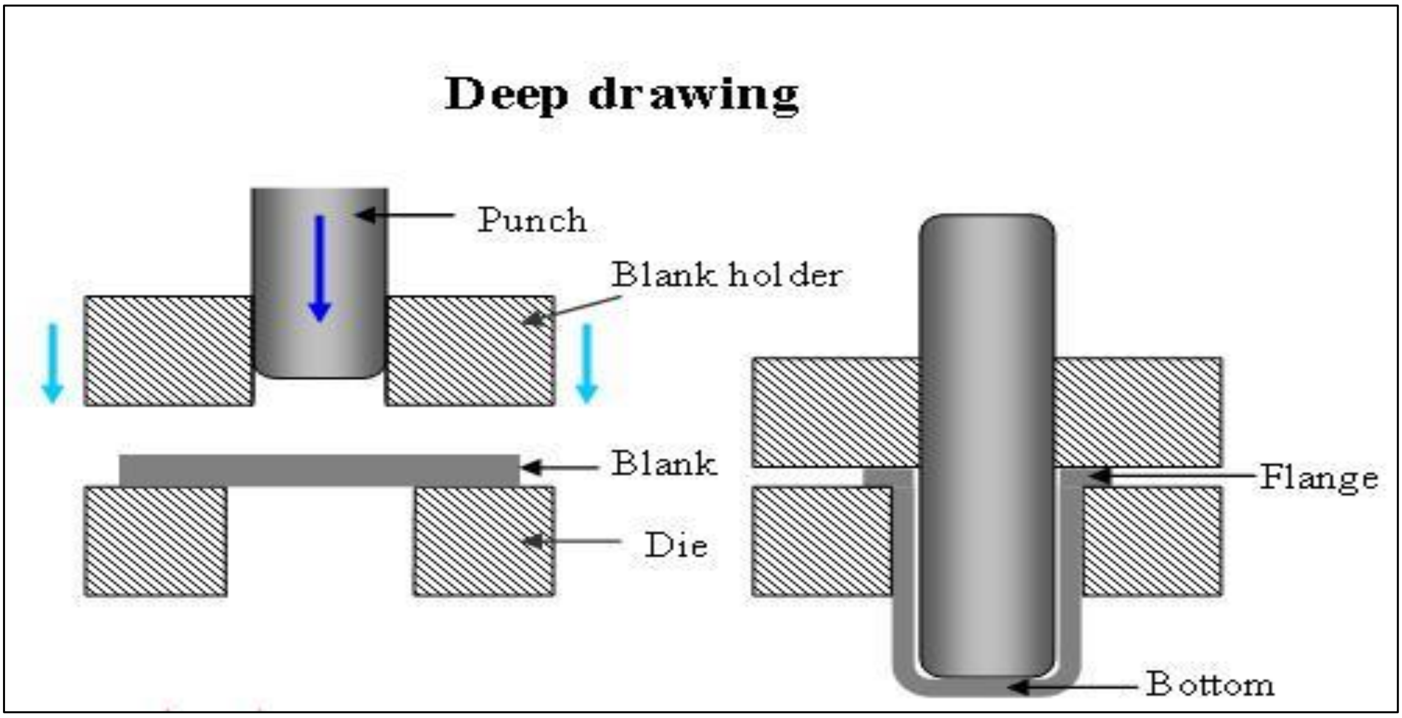


Fig 1 Basic Nomenclature of Deep Drawing

II. METHODOLOGY

- *Material Selection:*

Deep drawing processes commonly utilize cold rolled D grade mild steel due to its good ductility, adequate strength, and fine surface finish. Such material is a highly economical option for the deep drawing process which requires high accuracy and uniformity for the output parts. The properties of the steel make it coarsely thick walled able to undergo many shapes and it can be used in the making of items in small scale or even mass production. It is however, still nonthe less limited in its applications as very thick and very thin processes have potential unfavorable effects on the material and also the corrosion resistance is quite low. In summation cold rolled D grade mild steel is acceptable for processes that require deep drawing.

- *Design Considerations:*

Creating a utility cup that requires deep drawing involves careful attention to many aspects, in order to achieve desirable results. The shape, size and wall thickness of the cup need to be optimized with respect to the formability and strength of the material. In addition, the radius of the corners and walls and their angle also help a great deal in avoiding cracking and tearing during forming. Additionally, the design should include the punch and die clearances and the blank holder pressure to promote accuracy and repeatability in production. Besides, it is important to focus on the functionality of the cup and its final purpose in order to address the concerns of the design specification.

- *Deep Draw Process:*

To make a utility cup, the deep draw methodology encompasses a couple of operations which are blanking, drawing and ironing. Blanking refers to the cutting-to-size of a flat steel sheet to form a blank. A blank is then placed in die and a punch is used to push the blank against the die to make a cup shape. In the drawing stage, the cup that has already been drawn several times is again redrawn, and the process is repeated until the desired shape and size are achieved. The final step, which completes the whole operation, is the ironing stage, wherein a specific die is meant for intended purpose of straightening the walls of the formed cup inward to obtain even thickness of the cup. While this process is simple for the most part, control of elements such as pressure, speed and lubrication among other aspects is paramount in the manufacturing of a perfect utility cup.

- *Analysis & Simulation:*

Computational and experimental analyses using ANSYS will be essential in enhancing the design process of the deep draw for the utility cup. Through the development of a virtual prototype of the process, it would be possible for the designers to conduct experiments on the behavior of the materials and tools in working conditions and before any practical application so as to explore any problems and potential improvements. The ANSYS software gives the ability to deal with somewhat complex calculations and phenomena where nonlinear processes are taking place, for example, shearing of the material and interaction of the blank with the tools. This makes it possible to estimate stress, strain, and material flow among others, which helps in determining process parameters and tooling configuration for the desired product quality at minimum production expenditure. In addition to that, it is also possible to model the performance of the utility cup in ANSYS under numerous loads to evaluate if it meets safety and functional requirements.

III. DESIGN

Deep drawing parameters such as diameter, height and corner radius of the cup should be balanced to achieve deep drawn without defects such as wrinkled material, ripping and fractures. One more aspect that will influence the design is the mechanical properties if the CRD grade mild steel, particularly the greatest amount if yield stress, tensile stress and amount of elongation since his forming process will be applied for the cup. Also, attention should be given to the purpose of the product and desirability in terms of quality, look and functionality. Specific principles and instructions for the process of deep drawing can be used so that the utility cup can be designed with the required features and can be manufactured on a larger scale.

Fig 1 Design of Utility Cup.

IV. MODELING AND ANALYSIS

- *Catia:*

As structured, pliable model giving software, this means Catia V5 is a computer program, which assists the engineers and designers in creating objects which may be referred to as simulations with explicit details. It comprises of many tools and a number of workbenches as regards to certain functions for instance part design, assembly design and surface design. Most of the industries especially automobile, aeronautics and consumer goods sectors have embraced CATIA V5 as they can render faithful and intricate model designs. This version of CATIA software enables higher approval of designs as it comes with simulation and analysis features where designs can be tested rather than physically constructing them. Most users of CATIA V5 applications are designers and engineers, thanks to its user-friendly interface and copious amounts of tools and features geared towards creating advanced and intricate designs.

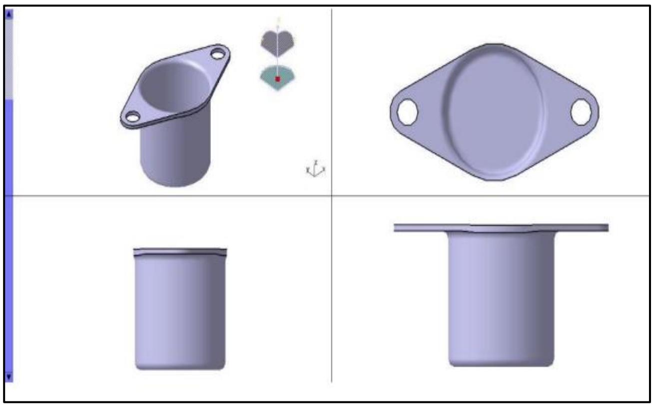


Fig 2 Cad model of a Utility Cup.

- *Geometry Description:*

In the deep drawing method of production, a piece of sheet metal is held in position over a die by a blank holder. After that, a punch is driven into the blank to pull the blank out in a cup shape. The design features of the tools utilized in deep drawing such as the punch, die, and blank holder become indispensable in detailing the final shape of the workpiece. Both the punch and die are generally given a rounding off radii to enhance the flow of materials. The blank holder exerts force on the blank to eliminate any possible wrinkling of the blank as well as aid in the even distribution of metal flow. The technology employed during deep drawing allows for the manufacture of fine components with intricate detail.

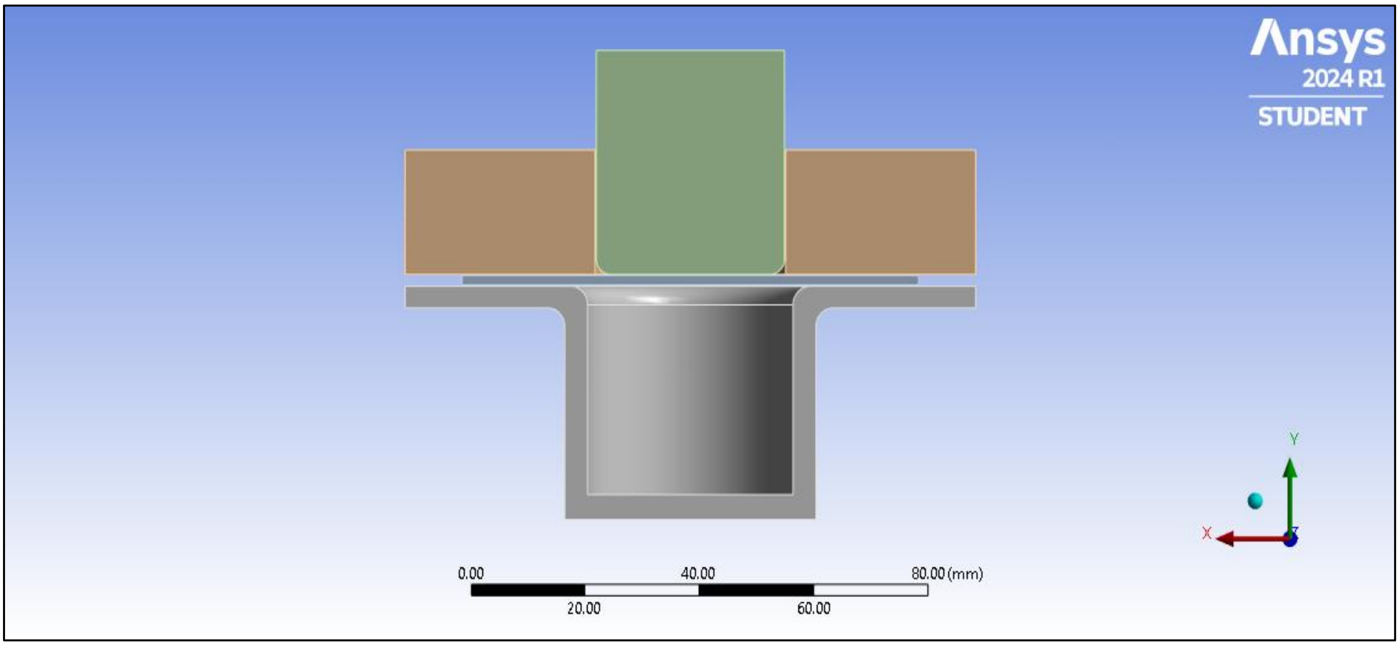


Fig 3 Geometry.

- *Mesh Description:*

To approximate the blank, punch, die, and blank holder a finite element mesh is created. The mesh usually consists of either quadrilaterals or triangles, and there is always a higher concentration of elements located in regions of high deformation. The purpose of the mesh is to model the fluid and deformation of a material during the deep drawing process. For a punch and a die, a structured mesh is often employed and an unstructured one for the blank in order to be able to deform it in thereby capturing distortion accurately. This mesh is then entered into the preprocessor of the Finite Element Method for the deep drawing simulation of the utility cup and the estimation of its final configuration. The process underlying the creation of a mesh is very important when it comes to reproducing the properties of the metal in the deep drawing operation.

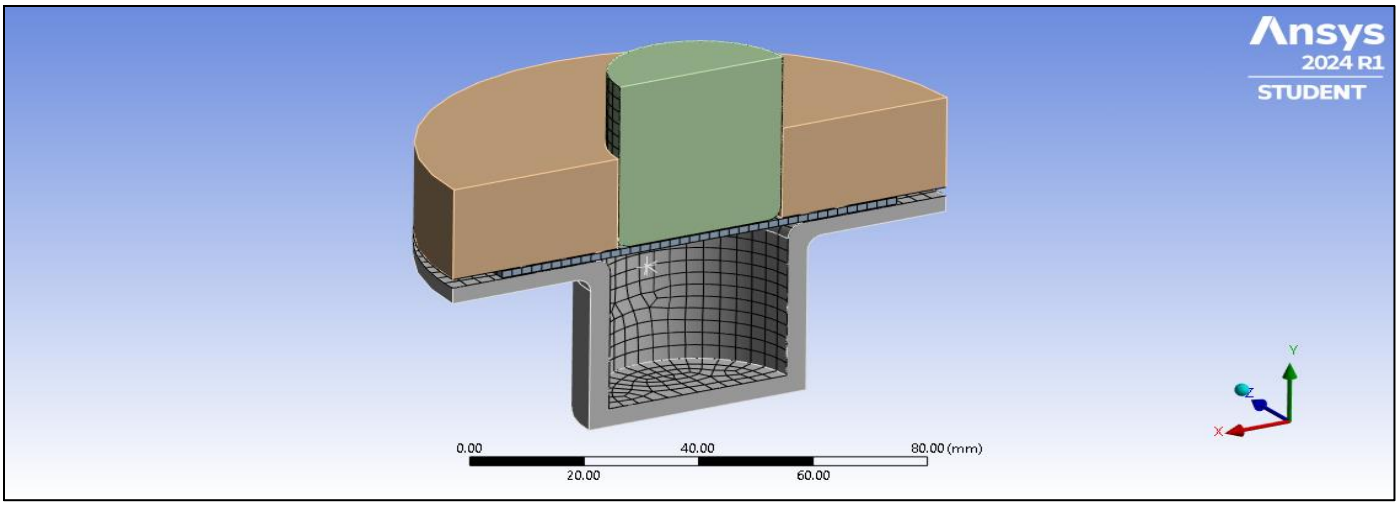
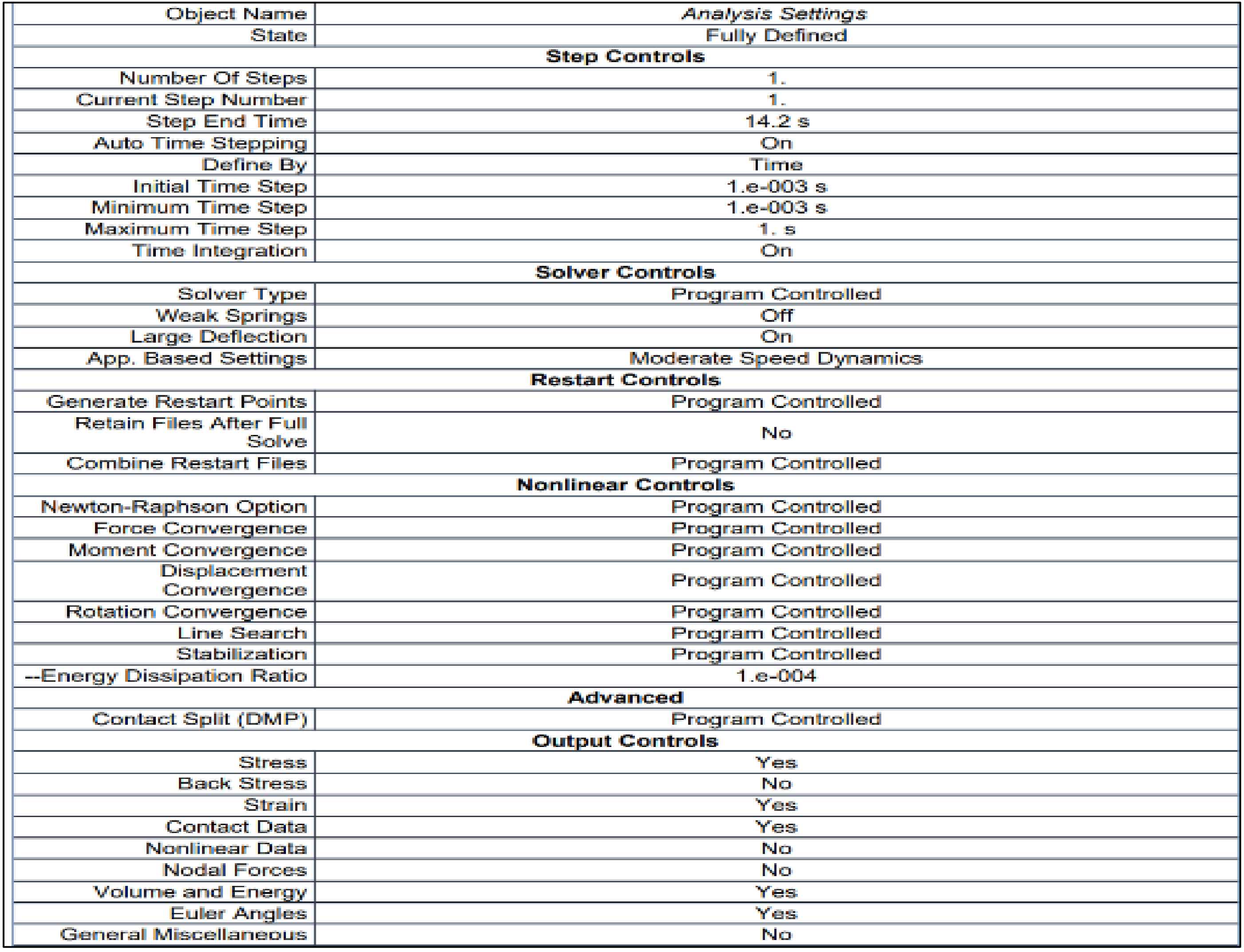


Fig 4 Meshed Geometry

➢ *Solver Settings:*

The solver settings encompass specifying the Solution Strategy, time integration and criteria for convergence. In this case, the modeling approach is usually toggled to 'Nonlinear' because of the large strains and plastic deformations experienced by the metal and nonlinear plastic material properties. The time integration method is set to dynamic in order to reduce the metal during drawing while accounting for the movement of the metal deep drawing process time. The convergence criteria are set in such a way that it computes the solution to a normal state, for example maximum iterations and convergence tolerance limits.

Table 1 Analysis Settings



Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	14.2 s
Auto Time Stepping	On
Define By	Time
Initial Time Step	1.e-003 s
Minimum Time Step	1.e-003 s
Maximum Time Step	1. s
Time Integration	On
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Large Deflection	On
App. Based Settings	Moderate Speed Dynamics
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
--Energy Dissipation Ratio	1.e-004
Advanced	
Contact Split (DMP)	Program Controlled
Output Controls	
Stress	Yes
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No

Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Damping Controls	
Stiffness Coefficient Define By	Direct Input
Stiffness Coefficient	0.
Mass Coefficient	0.
Analysis Data Management	
Solver Files Directory	C:\Users\Nadirge Chandravadan\Desktop\Waheed Project\Waheed Project_files\dp0\SYS-2\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	Yes
Solver Units	Active System
Solver Unit System	nmm

V. RESULTS AND DISCUSSION

The employment of ANSYS in the analysis of total deformation, stress and strain allows to understand the deep drawing operation of a utility cup in details. It helps in analyzing the blank's displacement and rotation, the stress distribution patterns and the strain developed in each and every element. The analysis of total deformation gives information concerning the shape and dimensions of the end product. Stress analysis indicates how and where the material will fail such as cracking, tearing or wrinkling. Strain analysis information helps understand how much deformation the material can endure before developing any residual stresses. The results of the analysis can be applied in improving the deep drawing technique and enhancing the standard of the resultant product. Examples of key results are; the height, diameter and wall thickness of the cup and stress and strain results. The analysis is aimed at reducing the defects caused by material failures to enhance the quality of the products. In the process's improvement high quantity of utility cups of good quality will be produced with low material waste and costs instead of the Optimising the process.

- *Total Deformation:*

The full deformation value of the utility cup is 32.864 mm, which reveals the total movement of the metal blank while deep drawing the cup. This is inclusive of the effect of punching and die movements, as well as the deformation characteristics of the material.

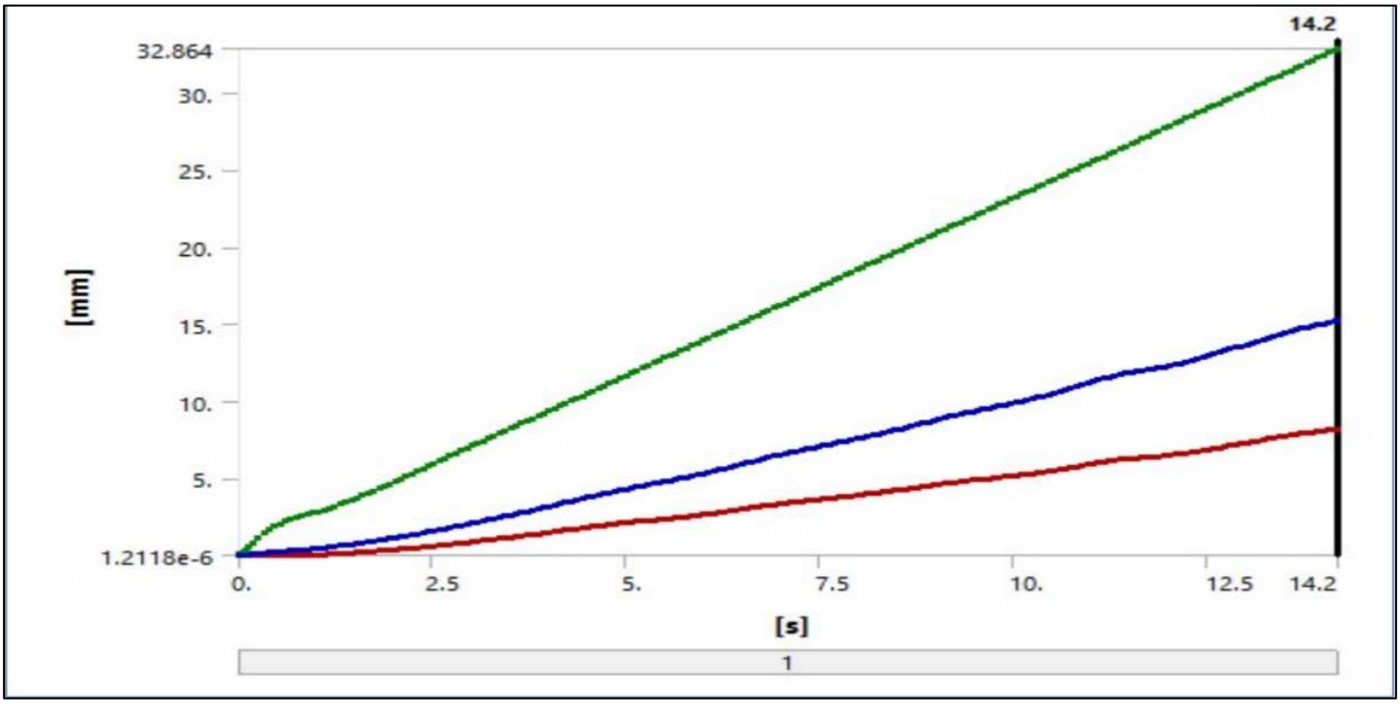


Fig 5 Total Deformation Graph

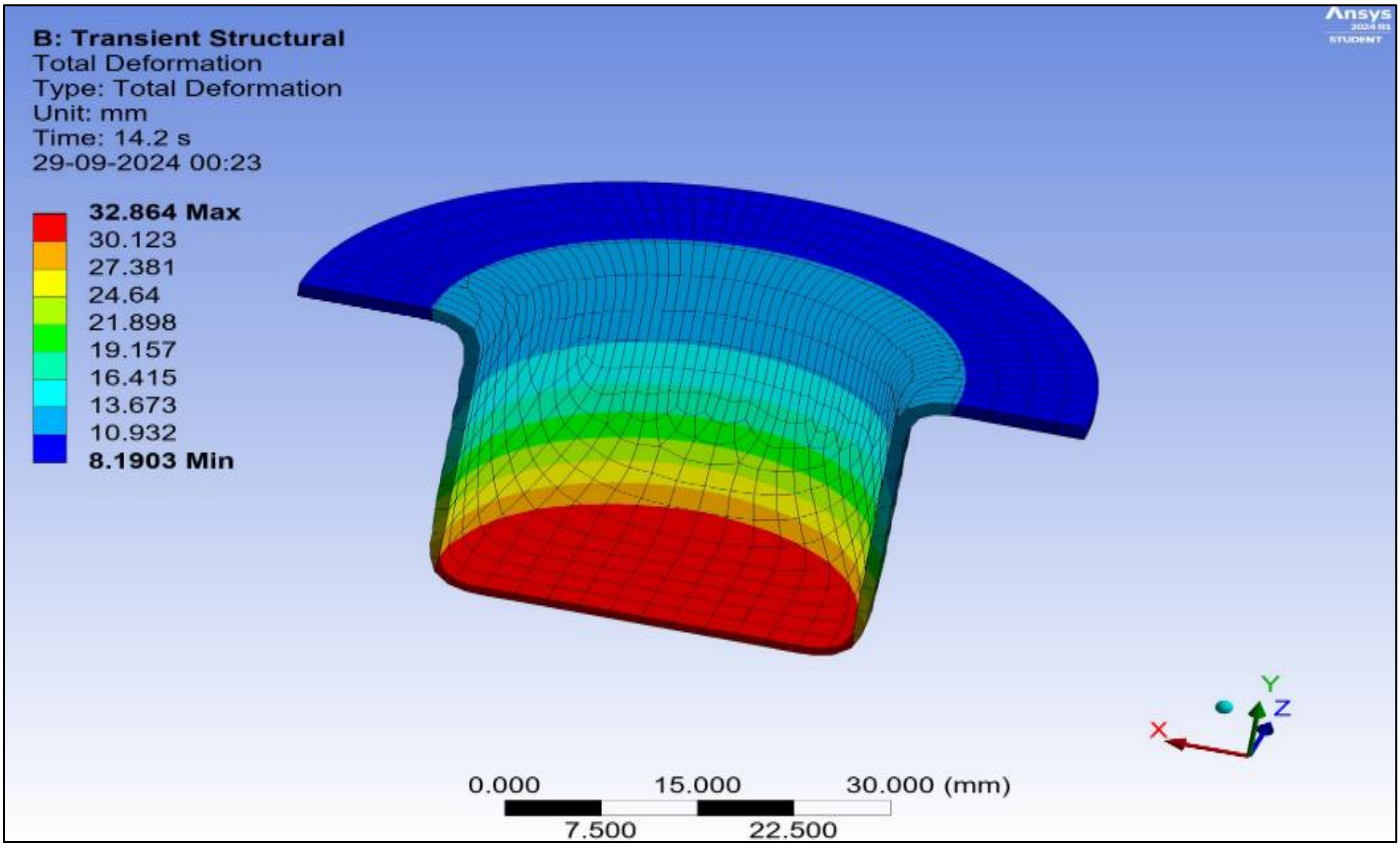


Fig 6 Total Deformation.

- ➢ *Equivalent Stress:*

The utility cup has an equivalent stress value of 1502.3 MPa, suggesting the maximum stress induced in the blank while deep drawing. This figure shows the combined impact of normal and shear stresses, aiding in providing a clearer picture on the state of stress in the material. The tests on equivalent stresses also show the failure of materials due to cracks, tears, and folding.

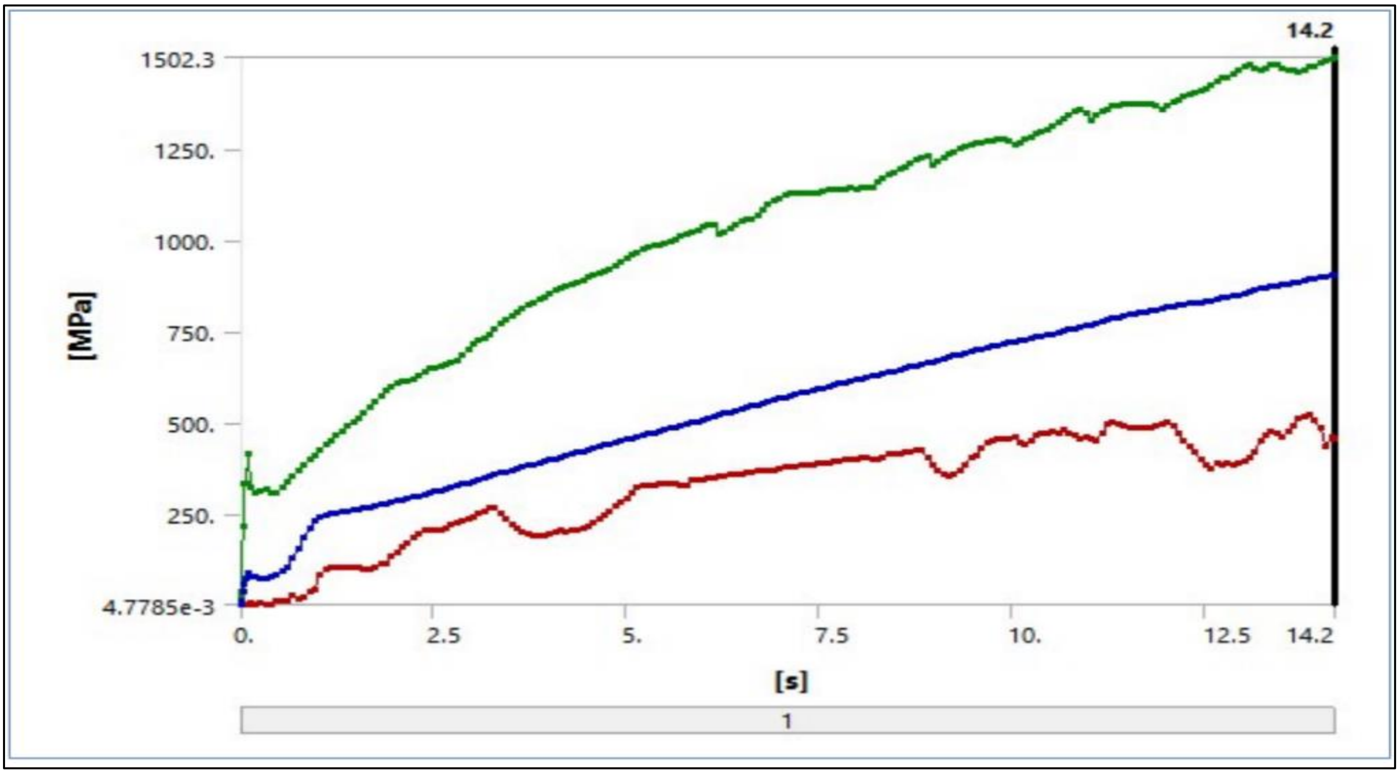


Fig 7 Equivalent Stress Graph

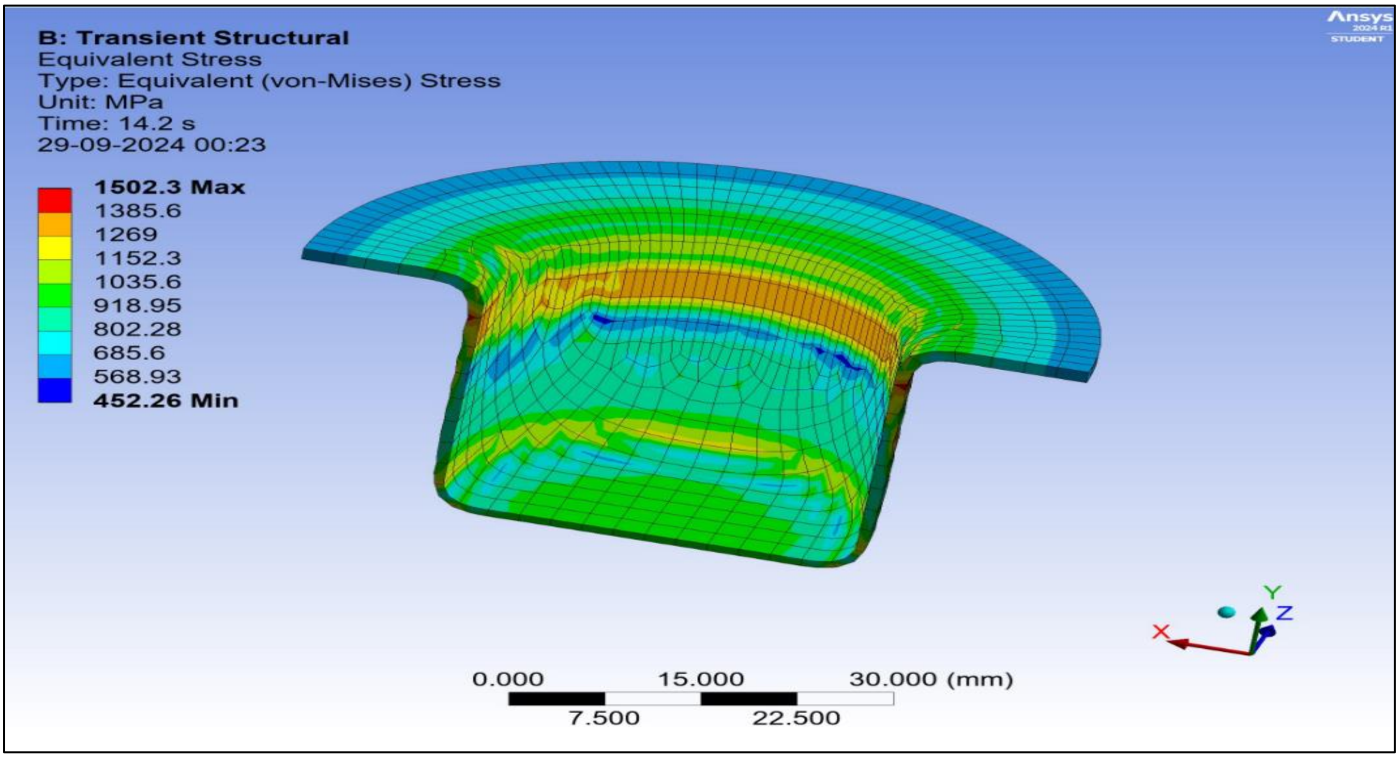


Fig 8 Equivalent Stress

- *Equivalent Elastic Strain:*

The utility cup has an equivalent elastic strain of 0.0076444, which is the maximum elastic distortion afforded to the blank in a deep drawing operation. This number characterizes the ability of that material to undergo elastic deformation and go back to its original shape upon removal of the external loads. The analysis of the equivalent elastic strain is useful in understanding the mechanisms of deformation of the material and provides assessment of material failure criteria and residual stress level as well.

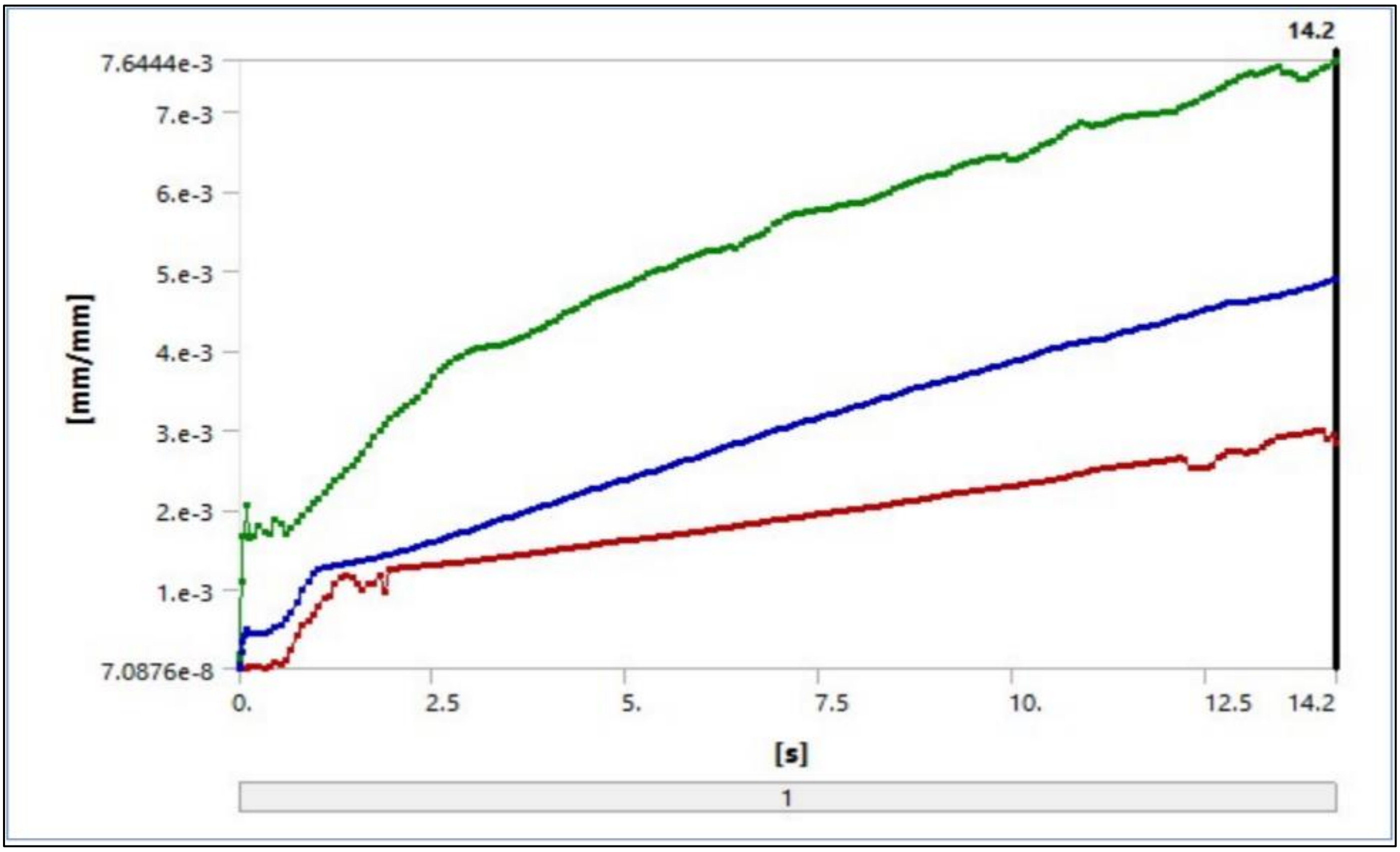


Fig 9 Equivalent Elastic Strain Graph

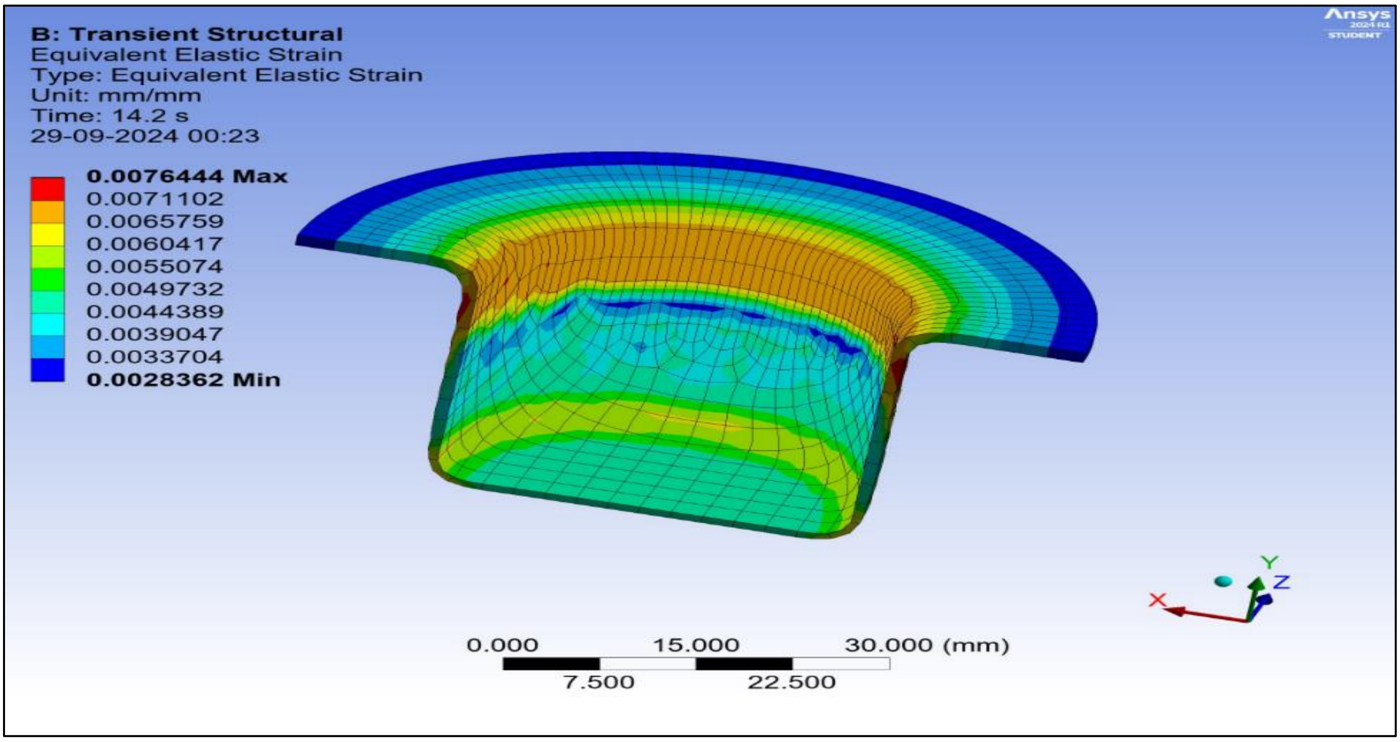
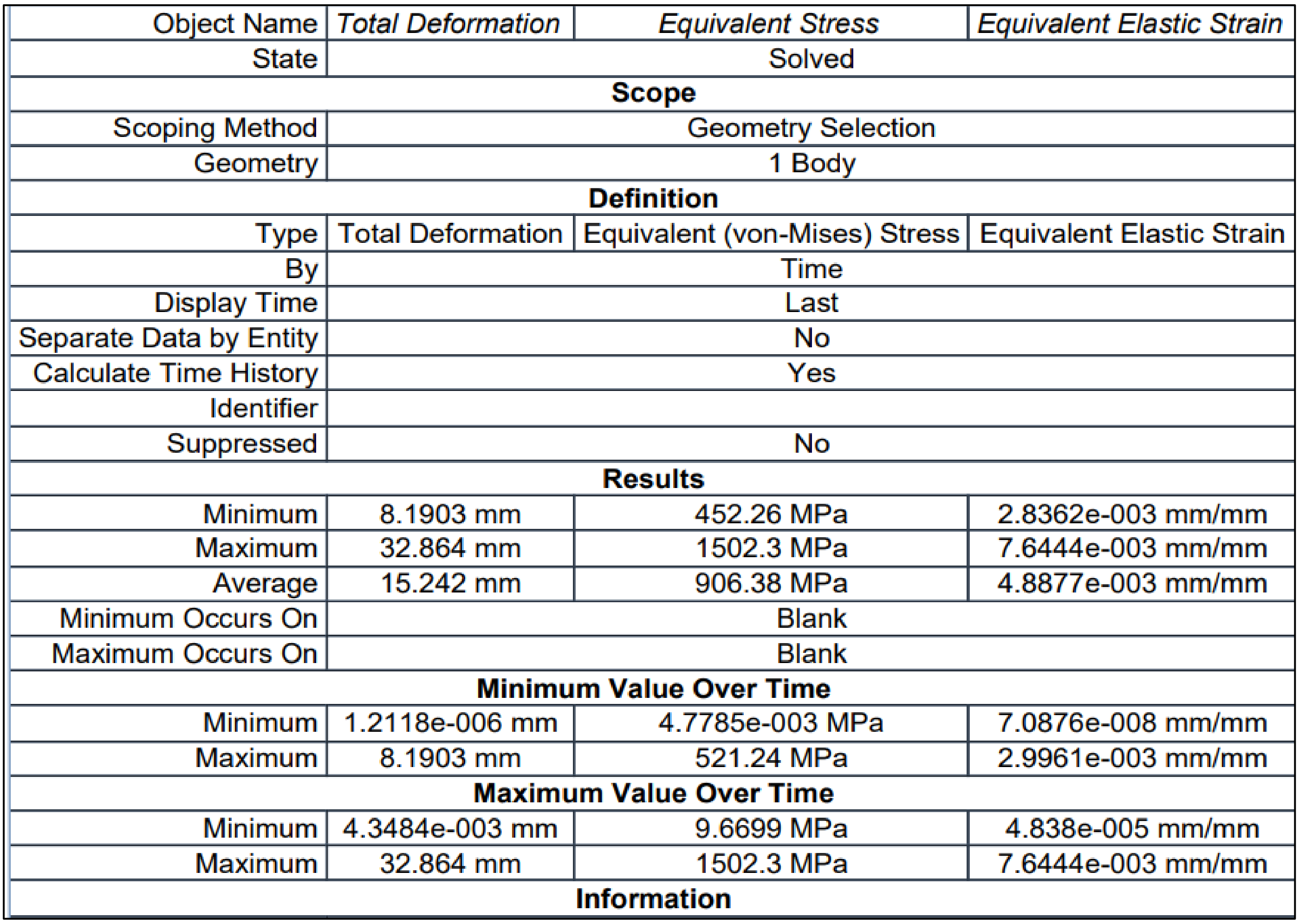


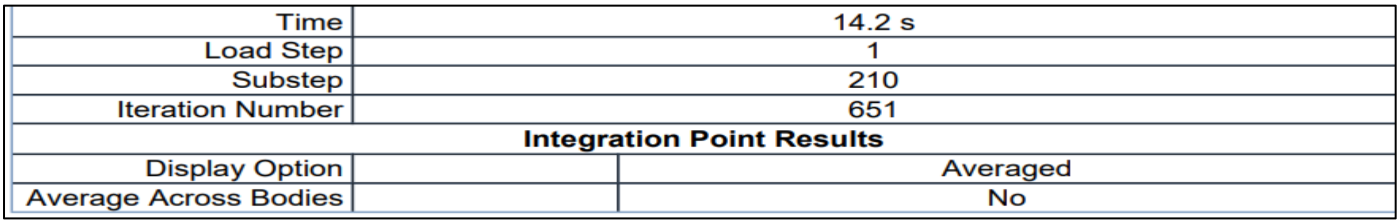
Fig 10 Equivalent Elastic Strain

- *Result*

Table 2 Result



Object Name	*Total Deformation*	*Equivalent Stress*	*Equivalent Elastic Strain*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body		
Definition			
Type	Total Deformation	Equivalent (von-Mises) Stress	Equivalent Elastic Strain
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	8.1903 mm	452.26 MPa	2.8362e-003 mm/mm
Maximum	32.864 mm	1502.3 MPa	7.6444e-003 mm/mm
Average	15.242 mm	906.38 MPa	4.8877e-003 mm/mm
Minimum Occurs On	Blank		
Maximum Occurs On	Blank		
Minimum Value Over Time			
Minimum	1.2118e-006 mm	4.7785e-003 MPa	7.0876e-008 mm/mm
Maximum	8.1903 mm	521.24 MPa	2.9961e-003 mm/mm
Maximum Value Over Time			
Minimum	4.3484e-003 mm	9.6699 MPa	4.838e-005 mm/mm
Maximum	32.864 mm	1502.3 MPa	7.6444e-003 mm/mm
Information			



Time	14.2 s	
Load Step	1	
Substep	210	
Iteration Number	651	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

VI. CONCLUSION

The deep drawing process of the utility cup executed through ANSYS has given understanding of the cup under different loads. The total deformation of 32.864 mm indicates displacement of the metal blank however the equivalent stress of 1502.3 MPa also indicates that these stresses may be higher than the yield strength of the material. The equivalent elastic strain of 0.0076444 shows that elastic deformation is considerable, and this may compromise the cup structure as well as performance. The simulation also avails the chances of improvements such as varying the punch and die design, materials used, and other process parameters so as to enhance quality and reduce wastage of materials. Consequently, manufacturers are in a position to manufacture utility cups of better quality and less materials at costs. In summary, the simulation emphasized the role of the finite element analysis in the understanding and the improvement of the deep drawing procedure.

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