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Finite Element Modeling for Numerical Simulation of Hydroforming of Tube with Axisymmetric Bulge

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ABSTRACT

Tube Hydroforming technology is a relatively new technology compared to other conventional stamping processes. Because of this there is low knowledge base for process control and product design. Because of prediction of correlation of axial feed with internal pressure and plotting of forming limits to obtain deformation zone are difficult to obtain manually and it will be quite expensive to check by trial and error. Understanding Tube Hydroforming process can be realized by computer simulation techniques. Simulation can be used to check and modify to select better product design coupled with tool design to achieve better process parameters. The obtained results in simulation will have practical significance in solving similar problems. It enables to investigate and broadens knowledge and stability of these kinds of processes. This can enhance productivity and expand Tube Hydroforming process in complex parts forming. This paper summarizes the results of simulation carried out by Computer Program ANSYS. The finite element modeling for numerical simulation of hydroforming of tube with axisymmetric bulge is carried out and the results of the study are presented and discussed with the future scope.

Keywords *– Tube Hydroforming technology, Finite Element Modeling, Numerical Simulation, Axisymmetric Bulge, Axial Feed, Internal Pressure.*

1. INTRODUCTION

Hydroforming is a specialized form of die forming that uses hydraulic fluids at high pressures to form metal which is at room temperature into a die cavity. It is a way of shaping malleable materials such as aluminium into light weight, structurally stiff and strong pieces in a cost effective way. Tube Hydroforming is a relatively new technology as compared to other conventional stamping processes. But with the advancements of computer controls and high pressure hydraulic systems, this technology has become a good means for high volume production. Modern machines with computer controls have independent control of counter pressure, internal pressure and axial feed increasing the capability of material shaping. The special importance given on light weight vehicles design also increases the requirement of parts produced using this technology.

The Tube Hydroforming process is a type of soft tool forming technology where fluid is used as a soft tool for applying internal pressure and is being developed rapidly in the past decades. Pre-formed tubes are placed in the die and sealed at ends. Then a combination of compressive axial force and internal pressure is applied to deform the tube from elastic to plastic stage.

The various advantages of Tube Hydroforming process are (a) light weight products (b) enables new and complex shapes easily (c) increase in strength and stiffness (d) assembly for welding eliminated (e) increase in dimensional accuracy (f) fewer secondary operations (g) fewer scrap. There are also few drawbacks of Tube Hydroforming process such as (a) slower cycle times (b) High cost of equipment (c) less knowledge base for product design and process control.

2. NEED FOR NUMERICAL SIMULATION

Tube Hydroforming process is becoming widely used and hence several issues has to be addressed such as material of tube, pre-form design, selection of lubricant, process control etc. Due to low knowledge base the trial and error method will result in high expenses. Therefore, numerical simulation will help to develop the process and increase the knowledge base about the process. The reasons for the interest in computer modeling of the tube hydroforming processes are mainly economical. Since the majority of tube hydroforming processes require high pressures it is not possible to do try-outs using soft tooling. All the try-outs are performed on hard tooling to verify the process control parameters such as internal pressure and axial feed variations in time. If changes are needed to be done on the tooling after they are manufactured it will be very expensive and tedious. Therefore, numerical simulations are now being used to develop computer models to check and fine tune the product design and process control before the manufacturing of hard tooling to avoid the loss of expenses and time.

2.1 Part Geometries

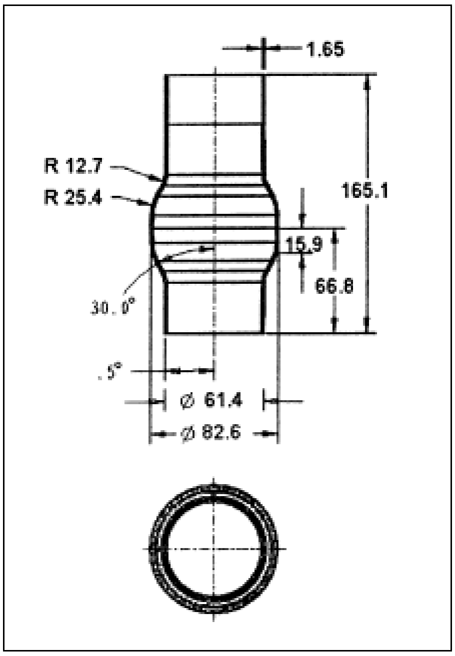

Fig 1: Part geometry formed in the experiment is a tube with axisymmetric bulge

The outside diameter of the tubing is 63.5mm (2.5 in.) with a wall thickness of 1-2mm. The blank length of the tube is designed to be 177.8 mm (7.00 in.). An expansion of 33% in diameter was formed in the experiment.

2.2 Tubular Blank Geometry and Material Properties

A 2.5 in., diameter and 7.0 in. long tubular blank was used in the experiments. The material used for the simulation is aluminum alloy (AA) 6061-T6. The material properties of Aluminium Alloy 6061-T6 Tubing are given in the tables 1.

Properties	Aluminium Alloy 6061-T6 Tubing
Thickness	t = 1.60mm
Outside Diameter	OD = 63.6mm
Young's Modulus	E = 70GPa
Poisson's Ratio	v = 0.3

Table 1: Properties of Aluminium Alloy 6061-T6 Tubing

2.3 Numerical Simulation of Tube Hydroforming Process

Various software packages available in the world market are capable of simulating the tube hydroforming process. Explicit and implicit programs are available. The various software packages that can be used to simulate tube hydroforming process are INDEED, LS-DYNA, PAMSTAMP, ANSYS, DEFORM, HYPER-FORM etc. In this study ANSYS was used to simulate the tube hydroforming process.

The finite element modeling and meshing is carried out in ANSYS. Then the load is applied prior to solving the axisymmetric model.

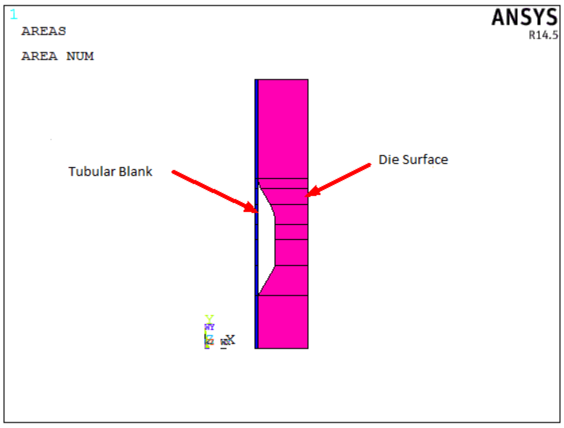

Fig 2: Finite Element Model

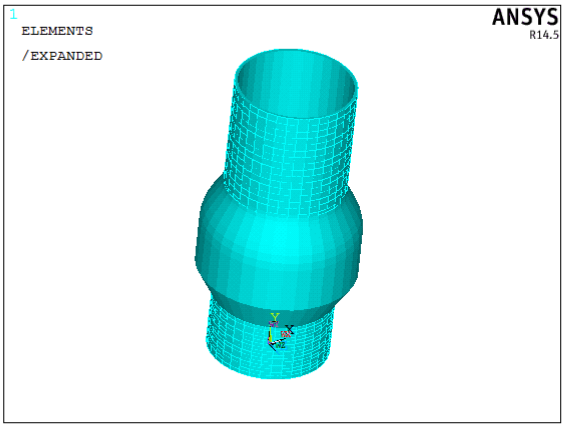

Fig 3: Geometry of Meshed Model

Figure 2 shows the Finite Element Model of the tubular blank and the die surface. The finite Element Model is axisymmetric. Figure 3 represents the complete geometry of the meshed model before applying internal pressure and axial load.

The internal pressure applied to the part is 57MPa. The various figures given below are the plots of displacements and von Mises stresses at different times of simulation. The figures show how the process sequence of tube expansion.

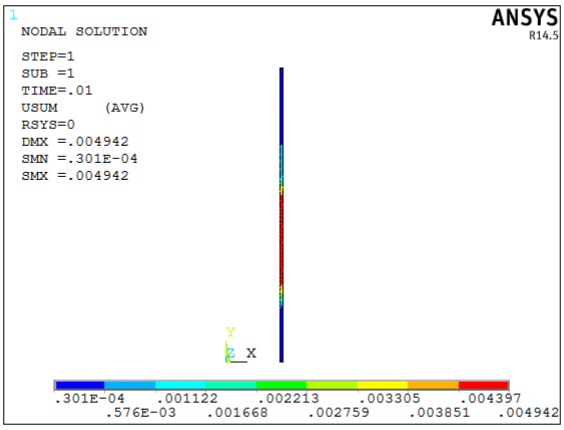

Fig 4: Displacement at time = 0.01seconds

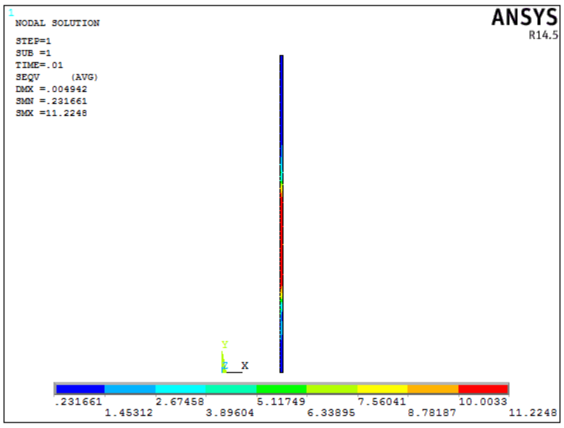

Fig 5: von Mises stress at time = 0.1seconds

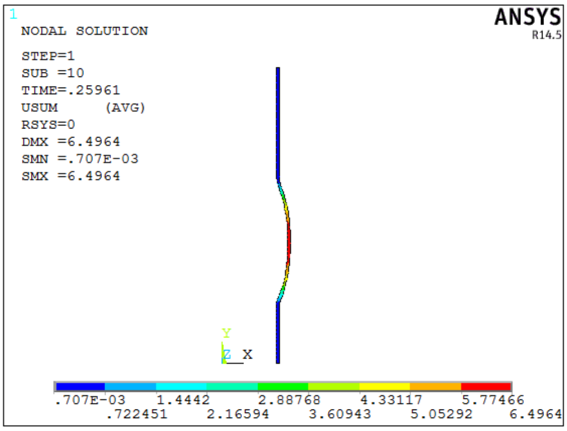

Fig 6: Displacement at time = 0.25961seconds

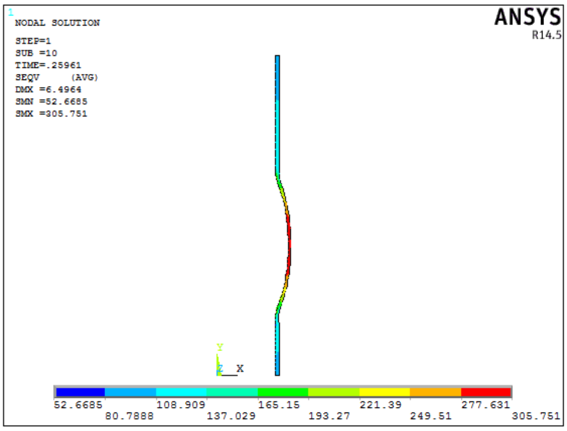

Fig 7: von Mises stress at time = 0.25961seconds

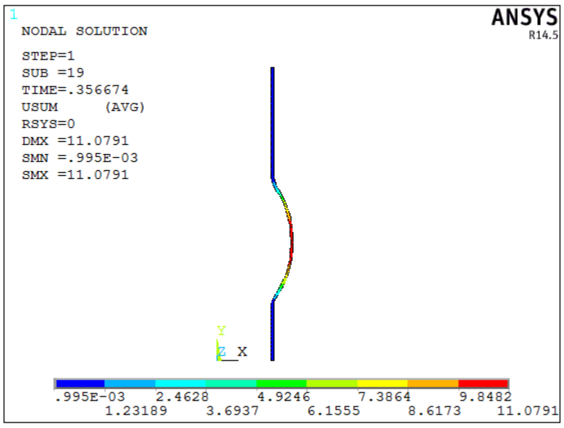

Fig 8: Displacement at time = 0.35667seconds

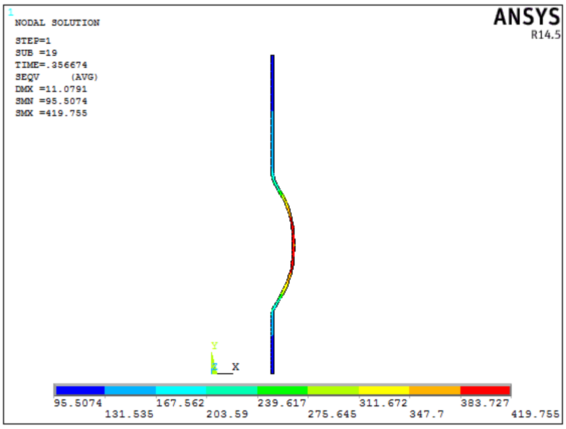

Fig 9 von Mises stress at time = 0.35667seconds

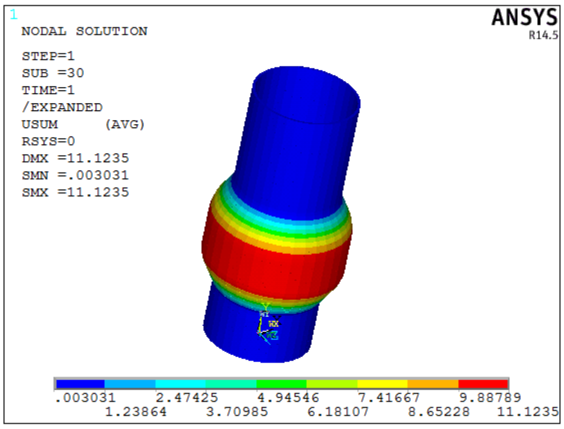

Fig 10: Final displacement

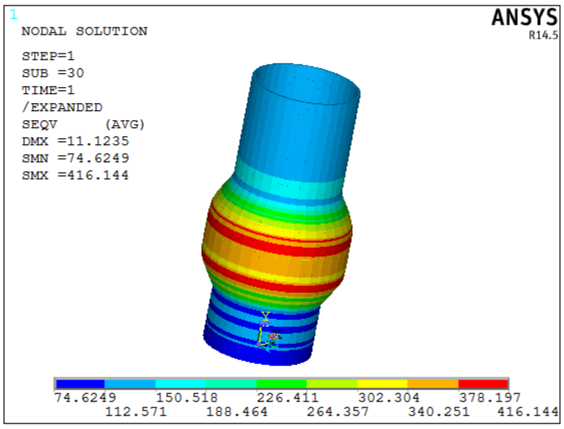

Fig 11: Final von Mises stress

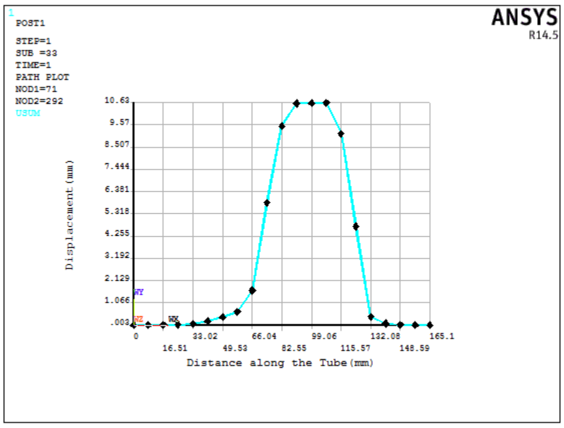

Fig 12: Plot of Displacement curve

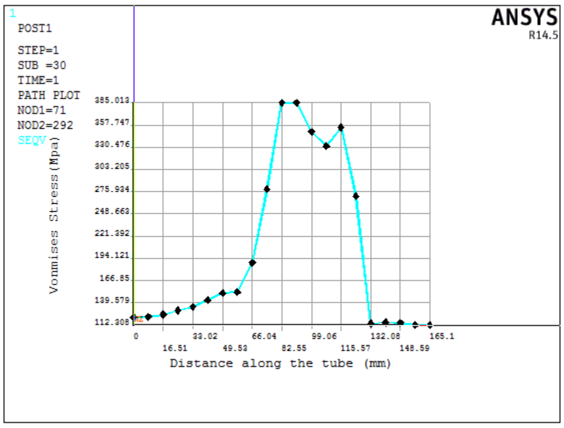

Fig 13: Plot of von Mises curve

Figure 4, 6, 8, 10 represents the displacements at different steps of the simulation process. Figure 10 represents the final displacement plot of the complete model and the maximum displacement is 11.1235mm.

Figure 5, 7, 9, 11 represents the von Mises stress at different stages of the simulation process. Figure 11 represents the final von Mises stress induced in the model and the maximum von Mises stress is 416.144MPa.

Figure 12 represents the graph of Displacement vs the distance along the tube and Figure 13 represents the graph of von Mises stress vs Distance along the tube.

3. CONCLUSION

Many researches and investigations of tube hydroforming have been carried out which has allowed the manufacturing of a variety of workpieces in a mass production. But, compared to the conventional stamping, the process is still relatively new, and hence, there is very less knowledge base for tool and process design for tube hydroforming process. So, a better understanding and clarity of the computer modeling will help in a lot to develop reliable control strategies for the internal pressure, axial feed and the counter pressure to improve material shaping capabilities of tube hydroforming technology.

In this study, much has been learned about the simulation of the tube hydroforming process, but many items need to be studied further to gain better understanding of the process fundamentals. Due to the involvement of high pressures and costly equipment in tube hydroforming process, trial and error is not feasible. So a better way to understand the tube hydroforming process is by the use of computer modeling. A variety of predictions by numerical simulation helps the engineers to understand the process and make necessary changes before manufacturing the hard tools.

Computer simulations of the hydroforming process are successfully used in many applications to form part and process design. However, better fracture and buckling evaluation modules need to be employed in the process modeling to evaluate the formability.

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