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Tube Forming using Hydroforming Technology and analyzing the Process on Explicit Dynamics

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Abstract: Tube forming being the most unified need for every automotive company, needs to be taken care of throughout the manufacturing process. Various automotive sectors have range of complex geometries of tubes and these geometries are classified by group technology. The THF process enables these sectors to produce tubes that are light in weight, without causing any losses in the material strength after the THF process. This study describes the Analysis of THF process for a simple circular c/s tube which is converted into rectangular tube. The equivalent Von-Mises stress generated is the main factor for THF process in this study. Material of the tube is E34 4012A CS. MISO is the plasticity model used and Explicit Dynamics solver is used on ANSYS.

Keywords: THF, MISO, Explicit Dynamics, ANSYS, Von-Mises stress.

I. INTRODUCTION

Tube hydroforming, THF contrives to be the emerging technique for forming the tube having complex geometry. Hydroforming uses fluid pressure to form the components which has intricate corners and edges that can be damaged easily when formed with other forming processes. The normal forming of tube has stages that undergoes various processes and thus the mechanical as well as chemical properties are likely to get changed in the final product, the strength of the final product thus changes. Tube Hydroforming causes change in the mechanical and chemical properties as well, but to an extent which does not affect the requirements of the final product. It is of utmost need to consider the maximum pressure up to which the tube can behave to be ductile without bursting. THF is a replacement to conventional forming, as it uses the high pressurized fluid to form the blank instead of the solid die as a counter mould that is been used in case of deep drawing.

A. Classification of Hydroforming

Hydroforming can be classified into two different categories: Depending on the pressure, Depending on the Application.

1) *Depending on the Pressure: a)* Low Pressure Hydroforming- Low Pressure Hydroforming has the fluid pressure (water pressure) range 80MPa to 450MPa b) High Pressure Hydroforming- High Pressure Hydroforming has the fluid pressure above 450MPa, used for complex geometry.
2) *Depending on the Application: a*) Sheet Metal Hydroforming- Sheet Metal Hydroforming has Fluid pressure ranging below or equal to 100MPa. b) Tube Hydroforming- Low pressure and High Pressure Tube hydroforming both can be successfully achieved in case of tube hydroforming depending on whichever is suitable for the purpose, both could be analysed and whichever turns out to be the best should be used.

B. Working of Hydroforming

A pre-bended tube is placed in a lower die, which is further closed by upper die, axial punches mounted on the shaft close the ends of the tube. Now internal hydrostatic pressure is imparted. Hydroforming works on the principle of pressurized internal fluid which forms the metal. Implication of internal hydrostatic pressure causes the metal to form which is not possible to be accomplished without the axial punches, which gives compressive force. The force imparted from the upper die is also a crucial parameter to be considered. Sheet hydroforming works on the similar principle, as that of traditional forming techniques, except the solid upper die is replaced by hydrostatic pressure. Increase in the internal hydrostatic pressure may cause bursting and increase in axial forces may cause wrinkling or buckling whereas increase in both may end up giving poor quality products as the outputs, thus the pressure and the forces are meant to be controlled throughout the process.

C. Advantages of Hydroforming

Hydroforming simply replaces the conventional forming methods which has male and female parts thus allowing a more widespread applications of complex geometry, which otherwise becomes a long process, as complex parts requires intricate corners and welds at

certain points. The cross-sectional changes across the length of the tube, non-linear structure makes the forming process far more difficult after welding the tube. Several subassemblies can be replaced by single hydroformed component.
Finishing of the product obtained has high degree than the conventional methods. The products are light in weight, cost effective, reduction in part producing time and possess better mechanical properties.

D. Applications of Hydroforming

Engine cradles, Chassis members, T- joints, Side members, Air ducts, Agricultural components, Medical Pumps, Aircraft parts, Bicycle frames, Plumbing parts, musical parts and frames etc.

II. MATERIAL AND METHODOLOGY

In current study the Carbon steel, E34 4012A grade is used in Tube Hydroforming process.

A. Material Properties

The chemical composition and mechanical properties of E34 4012A is as follows:

TABLE I
CHEMICAL COMPOSITION OF E34 4012A, CS

	C%	Mn%	S%	P%	Al%	Si%
E34 4012A	0.060	0.631	0.004	0.009	NA	0.236

TABLE II MECHANICAL PROPERTIES OF E34 4012A, CS

Tube size (mm)	117x.3.60
Condition	HRPO ASI Rolling
Strip Diameter (mm)	21.7
Strip Thickness (mm)	3.59
Area of Cross-Section (mm2)	77.9
O.G.L (mm)	49.86 / 24.93
UL (KN)	37.5
YL (KN)	34.5
F.G.L (mm)	66.5
Tensile Strength (MPa)	481.38
Yield Strength (MPa)	443
Elongation (%) min at 50 mml GL	33.4
Hardness (HRB)	79.00-80.00

Raw Material used here is end product from Tata Steels. The material is in the form of Coils, these mother coils are further hot rolled, welded, bended and then Hydroformed. After Hydroforming the final product is obtained. The final product is supplied to Tata Hexa for assembling as side members in their chassis. The die for front or the rear side members both are available.

B. Conventional method used for THF

The conventional method for tube hydroforming was setting parameters for particular material of tube hydroforming. The tube undergoes the process and final product represents the effects of the parameters, that were set by the operator. This may or may not lead to the desired output. Such trial and error method will definitely cause loss of time and have severe impact on the economy of the process due to material loss. This further disables the system to work efficiently.

The algorithm through which the process undergoes needs a lots of patience for the operator when fresh products are the ultimate target. To go through this process and getting the optimal result is difficult, in one go. The trial and error may be long lasting and may or may not be feasible if the target is to be achieved within specific period of time. The algorithm through which the product is manufactured is as follows

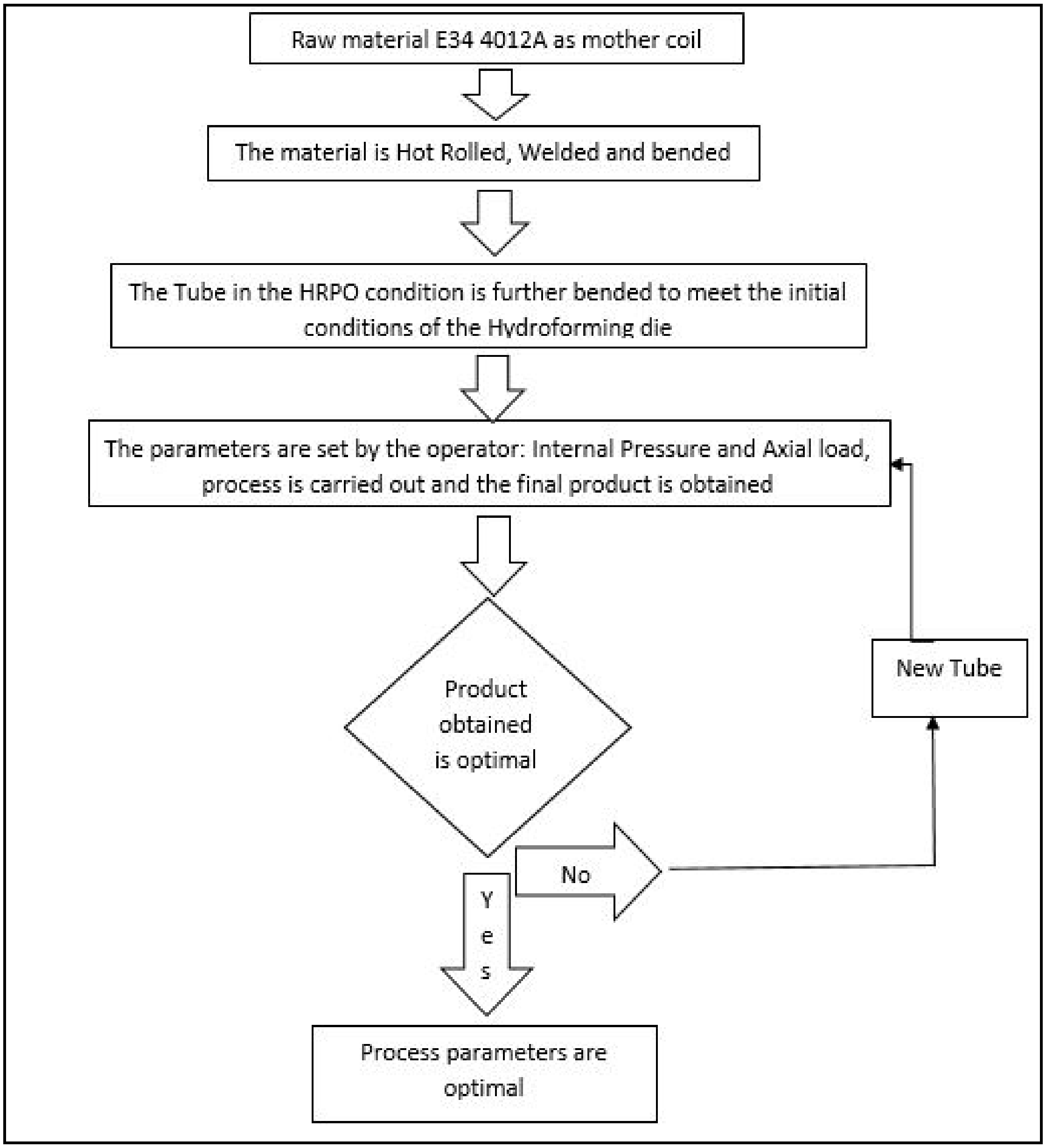

Figure 1 Algorithm followed by Conventional THF Process

C. THF based on ANSYS, Explicit Dynamics

THF based on ANSYS deals with the major problems linked to the conventional method. There are losses which results in the ineffective process plan strategy. The process should be planned in such a way that there are minimal losses and good percentage of profit that grows along with the manufacturing.

Analysis and Design Software plays important role when it comes to developing a model and confining a path which it goes through. There are analysis software's which shows the advanced and effective results when it comes to analysis of a process to obtain best possible results depending on the required outputs. Here in the following study, ANSYS software is used. Explicit dynamics is the solver that deals with the problems that relate to dynamic loadings. The THF process has nonlinear conditions which can only be dealt using explicit dynamics. The algorithm through which the effects of process parameters are analyzed:

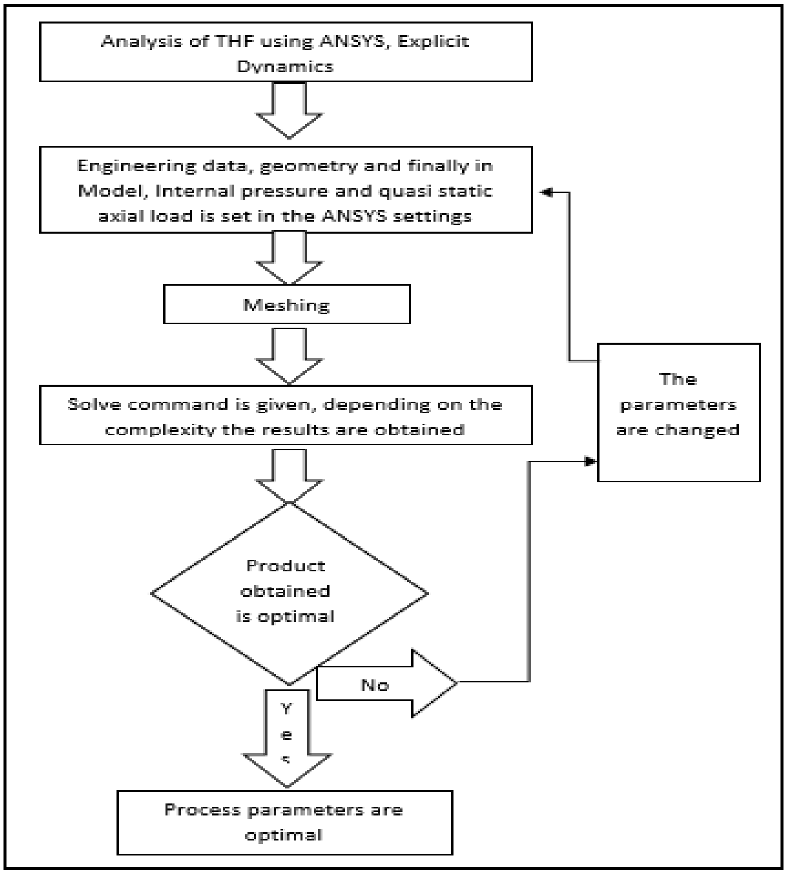

Figure 2 Algorithm followed by ANSYS, Explicit Dynamics

D. Methodology

ANSYS 18.2, Explicit Dynamics tools help users meet solution requirements of various complexities based on problem details and user expertise, thus this method undergoes various steps.

1) *Selection of the Hardening criterion :*The very initial step for any Analysis work is the engineering data which can only be obtained when material undergoes certain tests. Depending on the Analysis, ANSYS 18.2: Explicit Dynamics solver which uses MISO (Multilinear Isotropic Hardening) requires only Tensile test so as to obtain the true stress v/s strain graph. The Explicit dynamics solver has a lots of models amongst which some are based on Kinematic hardening whereas some are based on isotropic hardening The basic difference between the isotropic hardening and Kinematic Hardening is as follows:

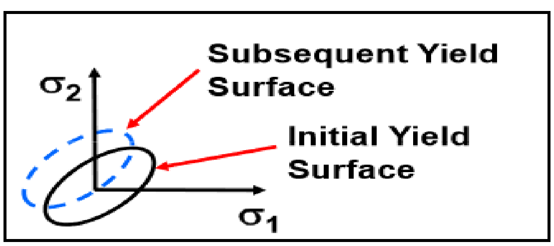

Figure 3 Kinematic Hardening

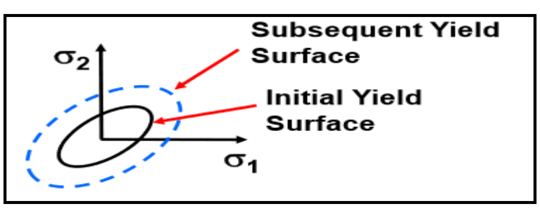

Figure 4 Isotropic Hardening

In Kinematic Hardening the yield surface remains constant in size and translates in the direction of yielding whereas in case of Isotropic Hardening the yield surface expands in all the directions with plastic flow. As there are many nonlinearities in THF and as the yield surface expands in all direction of yielding, therefore MISO is used in the study. The MISO requires various input parameters such as true stress and strain points which should be 10 points starting from the yield point at any given temperature for which the strain is zero. As we give 10 points as input the true stress strain plot can be observed as the input to MISO model. Plotting of stress strain curve enables observable loading and reverse loading cycles. The isotropic hardening is used for large strains or equivalent loads and not advised to be used in cyclic processes. The isotropic elasticity in MISO requires Poisson's ratio, Young's Modulus and density of the tube material used. The static structural steel is the default material used, E34 4012A is carbon steel and thus it should be added in the Engineering data. For E34 4012A, Poisson's ratio =0.3, Modulus of elasticity=2.1 x 1011Pa, Density =7850kg/m3 is given as data input in isotropic elasticity. The water temperature ranges from 24ºC to 28ºC. The tensile test results in the load v/s deflection diagram. This load v/s deflection diagram is converted to engineering stress strain curve using the mechanical properties obtained from the load v/s deflection diagram. There are calculations which gives stress strain points, but accurate results were required as the same engineering stress strain points are further converted to true stress strain points. The following can be used to convert the engineering stress strain points to real/true stress strain points.

Up until twice the strain at which yielding occurs:

$$\sigma = \sigma_{engg} \quad \text{and} \quad \varepsilon = \varepsilon_{engg} \tag{1}$$

Up until the point at which necking occurs:

$$\sigma = \sigma_{engg}\,(1+\varepsilon_{engg}) \quad \text{and} \quad \varepsilon = \ln(1+\varepsilon_{engg}) \tag{2}$$

Thus the final stress strain curve obtained is real/ true stress strain curve:

TABLE III MECHANICAL PROPERTIES OF E34 4012A, CARBON STEEL

True Strain	True Stress (MPa)
0	0.0001
0.002033	404.95
0.0025001	430.34
0.0050204	445.29
0.0088981	455.6968
0.0140418	462.35693
0.0296573	476.1953214
0.0645694	499.9087675
0.1790898	570.7205616
0.2897601	643.1885006

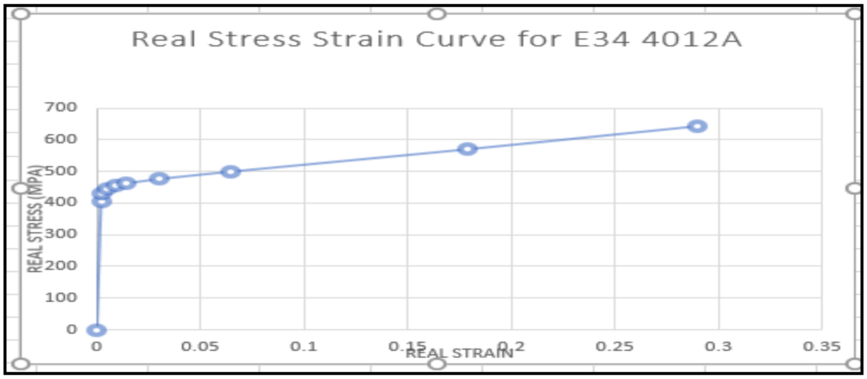

Figure 5 Real Stress Strain Curve

E. Engineering Data Input

The most important step in any analysis is Engineering Data Input as any kind of inaccuracy in it may cause large problems which may simulate in large deformations and strains and may not match the required output specifications. As discussed above the Multilinear Hardening requires Engineering data such as real stress strain curve, Poisson's ratio, Young's Modulus, density and temperature are to be given.

1) *Geometry:* Geometry can be imported from SOLIDWORKS, which is assembly of lower die and a tube. The same can also be made in the ANSYS geometry within the software. For the study half sectional assembly is considered to check the parameters. The OD of the tube is 117 mm Thickness is 3.6 mm and length is 200 mm. The c/s of the die is 136.05 mm wide (outer), 21.01 mm height from inside flat surface and 50 mm height from outside flat surface, 20 mm thick and length same as tube.

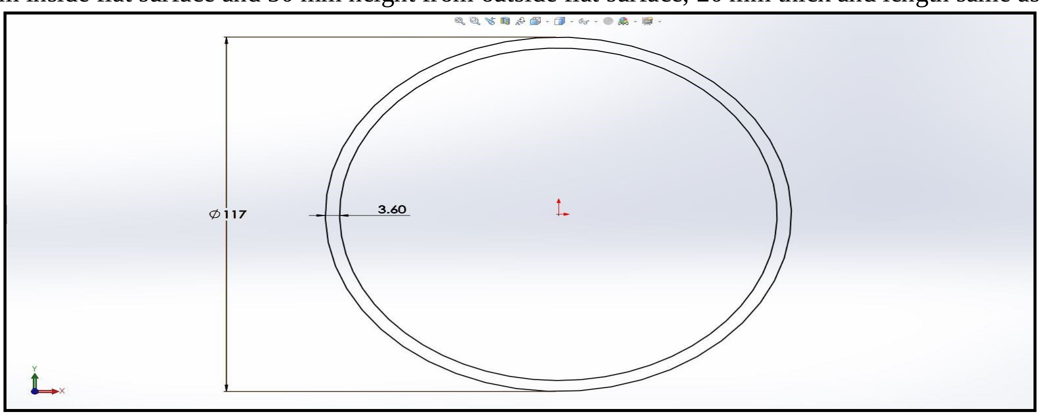

Figure 6 Circular Tube c/s

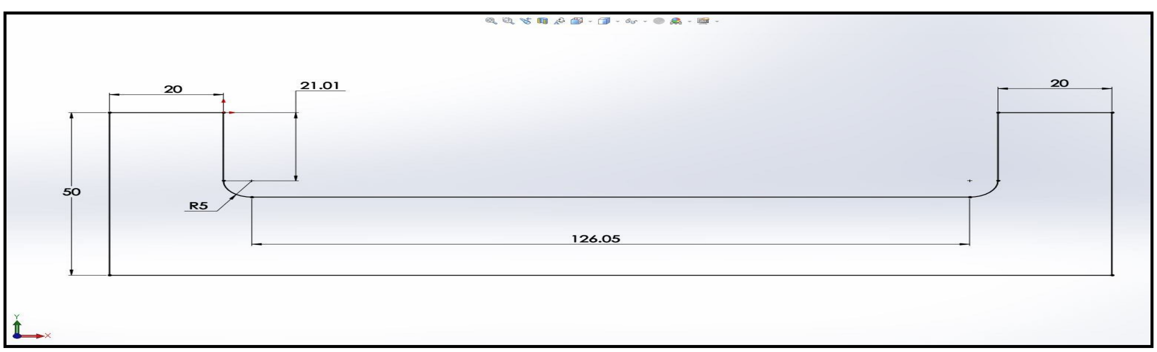

Figure 7 Die c/s

2) *Modelling:* Modelling is the most important step in ANSYS. The contacts are deleted and the die is kept rigid, Tube is made flexible and all the contacts are deleted. The default material for both is structural steel which has been changed to carbon steel for tube and for die structural steel is default material that the software selects. As mesh generation is done, model is discretized into elements depending on the geometry. For this study mesh generation creates coarse mesh. Further Body sizing for the die

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and Edge sizing for the tube is done which generates good meshing results. In the Body interaction, the friction is kept 0.2. All the analysis settings are done in the modelling stage. The meshing results for the tube on Explicit dynamics model results as follows:

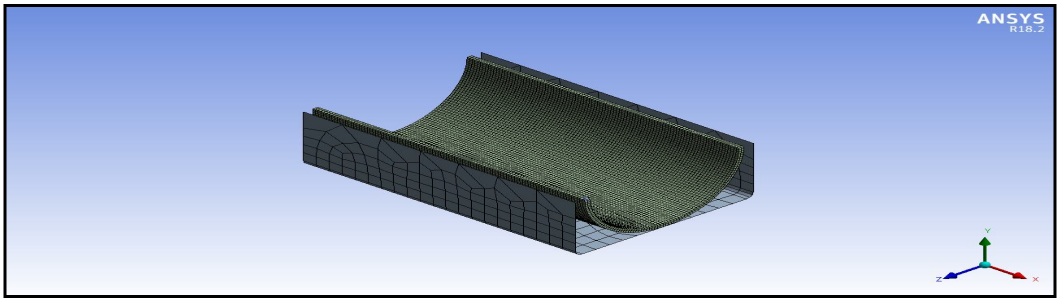

Figure 8 The meshing results for the tube and die on Explicit dynamics model

3) *Boundary conditions:* Defining the boundary condition for the given simulation is equally important as simulations are totally based on the user defined boundary conditions and serve for the requirements that could meet fully with the end results. For the above model the boundary condition is only the internal pressure which is applied to the inner surface of tube and the axial force which is applied via plunges. The axial force is quasi static and their resulting effects in the above problem are negligible. Thus only internal fluid pressure is considered for deformation.

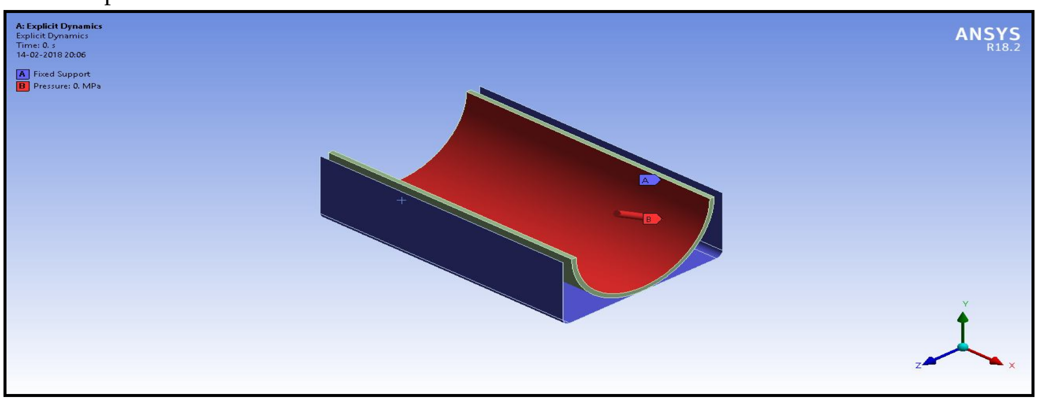

Figure 9 Flexible to Rigid connections and Internal pressure

As the Die surface is assumed to be rigid, it is also constrained in all degrees of freedom. The outer surface of the tube is flexible and thus takes the shape of die as the internal hydrostatic pressure increases. The pressure is not directly applied to the tube but slowly applied. The two step pressure application during the process is as follows:

4) *Iteration of Explicit Dynamics*

TABLE IV PARAMETERS FOR 1ST ITERATION

Time in milliseconds	Pressure in MPa
0.001s	150MPa
0.003s	300MPa

The end time given for the process is 30 seconds and when solved the results obtained were not optimal and the tube bursting is seen in the simulated results. The results obtained implied that the pressure was very high thus, the circular tube was formed into rectangular tube but it bursts in between the process.

5) *Iteration of Explicit Dynamics*

TABLE V PARAMETERS FOR 2ND ITERATION

Time in seconds	Pressure in MPa
0.001s	80MPa
0.003s	160MPa

The results obtained after solving for above parameters from this iteration are optimal and the Circular tube forms to a rectangular tube in 30s without bursting. The cause of Bursting was high internal pressure.

III. RESULTS AND DISCUSSION

A. Von-Mises Stress distribution

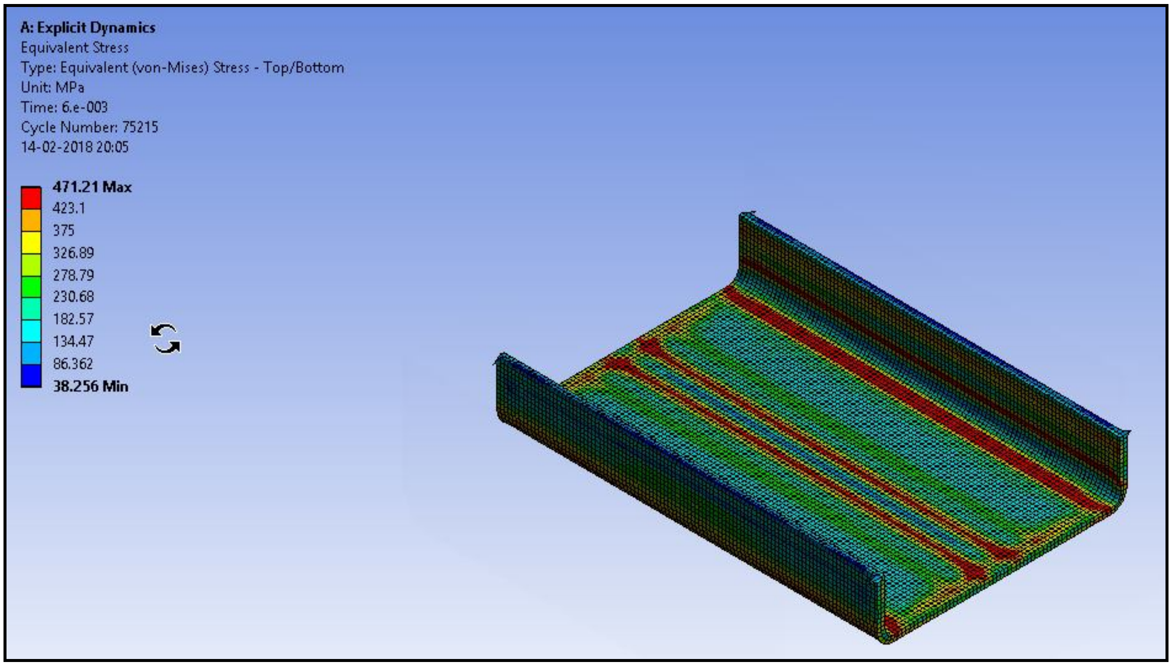

Figure 10 Von-Mises Stress Distribution after hydroforming a circular tube to rectangular

The Von- Mises maximum equivalent stress is 471.21 MPa which is above the yield strength and very much below the ultimate strength of the material.

B. Total Deformation

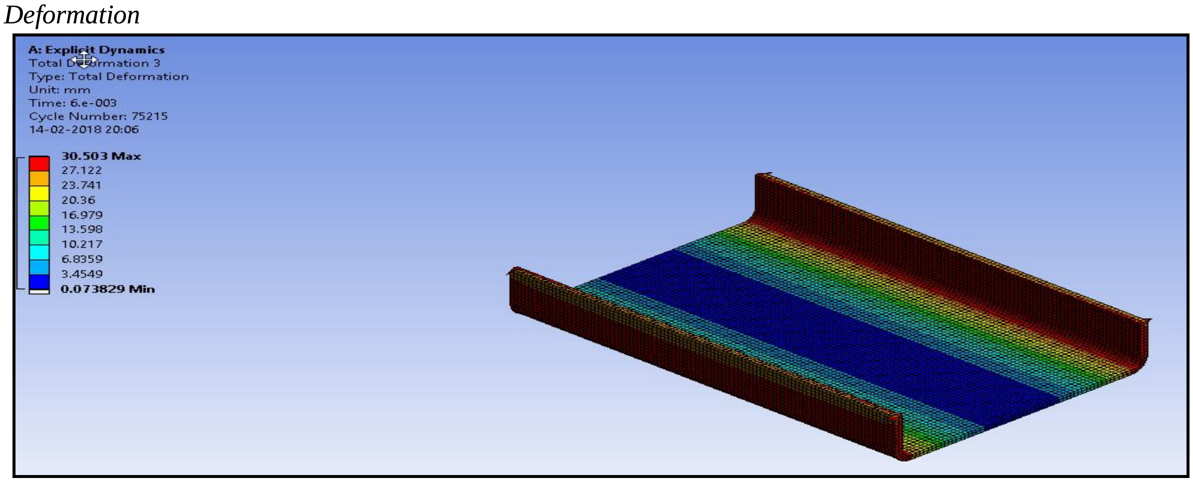

Figure 11 Total Deformation after hydroforming a circular tube to rectangular

The total deformation obtained is 30.503 Maximum.

VI. CONCLUSION

In the case study, E34 4012A CS tube was the material which was used for Hydroforming Process. The free Bulging criteria of Tube Hydroforming was Analysed. The Internal Pressure was the Boundary condition. The plunge that holds the tube in between the lower and upper die exhibits the force axially which is very small in this case and thus the force exerted was very small which could only hold the tube and also quasi static, slow and reversible. Therefore, the axial force is neglected in this study. Following important conclusions can be drawn from the results of the case study:

A. High Internal Pressure compared to axial Force can cause bursting of the tube.

B. As trial and error method gives results that may cause waste up to ‘n’ processes. Where ‘n’ tends to the number of iterations until the desirable result is obtained. No. of iterations depends on the technical skills of the operator and the operation head. Thus Material costs is saved by 20%-40% by using ANSYS: Explicit Dynamics.

C. There is reduction in time used for every setup that requires at least 15 minutes to settle the machine after removal of waste and to set parameters in the machine. Every 15 minutes that are wasted for such 4 failures in a month reduces 20 products that can be produced more. The calculations done are on an average scale considering from October’17 to Jan’18

VII. ACKNOWLEDGMENT

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REFERENCES

[1] Y. Shi, H. Jin, P.D. Wu , D.J. Lloyd, “Effects of superimposed hydrostatic pressure on necking and fracture of tube under hydroforming,” International Journal of Solids and Structures, 2017, Accepted manuscript for the Journal.

[2] R. Bihamta, Q-H. Bui, M. Guillot, G. D Amours, A. Rahem, M. Fafard, “Global optimization of the production of complex aluminum tubes by the hydroforming process,” CIRP Journal of Manufacturing Science and Technology, vol. 9, pp. 1–11, 2015

[3] G. Palumbo, A. Piccininni, P. Guglielmi, G. Di Michele, “Warm Hydroforming of the heat treatable aluminum alloy AC170PX,” Journal of Manufacturing Processes, pp. 1-9, 2015

[4] Yi-Chun Chen, Chih-Yu Chuang, Ming-Fu Lee, “Process parameter with high expansion rate of SUS304 tube hydroforming,” Procedia Engineering 81, pp. 2230 – 2236, 2014

[5] K. Sadasivan, P. Ganesh, “Experimental and finite element analysis of hydroforming process for stepped die,” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), pp. 18-22, 2014

[6] Ramin Hashemi, Karen Abrinia, Ahmad Assempour, “The strain gradient approach to predict necking in tube hydroforming,” Journal of Manufacturing Processes, pp. 51-55, 2013

[7] Aminu Saleh Mohammed, “The Hydroforming Process of an Automotive Part,” International Journal of Engineering Research and Development, vol. 8, no. 7, pp. 49-55, 2013

[8] Shuhui Li, Xianfeng Chen, Qingshuai Kong, Zhongqi Yu, Zhongqin Lin, “Study on formability of tube hydroforming through elliptical die inserts,” Journal of Materials Processing Technology, pp. 1916– 1924, 2012

[9] YANG Xiao-yu, “Tube Hydroforming Analysis Based on Ansys,” Applied Mechanics and Materials, vol. 232, pp 537-540, 2012

[10] A. Alaswad, K.Y. Benyounis, A.G. Olabi, “Tube hydroforming process: A reference guide,” Materials and Design, pp. 328–339, 2012

[11] Vijay. R. Parekh, Jay. Shah, B. C. Patel, “Review on Tube Hydroforming Process with Considerable Parametric Effect,” International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME), vol. 1, no. 1, pp. 117-123, 2012

[12] Angshuman Ghosh, Karan Deshmukh, Gracious Ngaile, “Database for real-time loading path prediction for tube hydroforming using multidimensional cubic spline interpolation,” Journal of Materials Processing Technology, pp. 150–166, 2011

[13] Lihui Lang, Huili Li, Shijian Yuan, J. Danckert, K.B. Nielsen, “Investigation into the pre-forming’s effect during multi-stages of tube hydroforming of aluminum alloy tube by using useful wrinkles,” Journal of materials processing technology, pp. 2553–2563, 2009

[14] C. Nikhare, M. Weiss, P.D. Hodgson, “FEA comparison of high and low pressure tube hydroforming of TRIP steel,” Computational Materials Science, pp. 146–152, 2009

[15] Nader Abedrabbo, Naeem Zafar, Ron Averill, Farhang Pourboghrat, Ranny Sidhu, “Optimization of a Tube Hydroforming Process,” www.redcedartech.com, pp. 1-6, 2009

[16] Chen Yang, Gracious Ngaile, “Analytical model for planar tube hydroforming: Prediction of formed shape, corner fill, wall thinning, and forming pressure,” International Journal of Mechanical Sciences, pp. 1263– 1279, 2008

[17] Mikael Jansson, Larsgunnar Nilsson, Kjell Simonsson, “On strain localization in tube hydroforming of aluminum extrusions,” Journal of materials processing technology, pp. 3-14, 2008

[18] P. Ray, B.J. Mac Donald, “Experimental study and finite element analysis of simple X- and T-branch tube hydroforming processes,” International Journal of Mechanical Sciences, pp. 1498-1518, 2005