CHAPTER 6 CONCLUSION AND SCOPE OF FUTURE WORK

6.1 Conclusion

1. In this paper, thickness distribution of elliptical bulged tube samples has been observed at different internal pressures along major as well as minor axis. Uniform wall thickness complex tubes could be manufactured at low fluid pressure to reduce the dependency on the need of traditional stamping, spinning, material removing and lots of die attachment arrangements. Mass production could be done with cheap die fabrication through wire cut EDM machine. Tube samples with complex shape are widely uses in automobile, aerospace and other area such as manufacturing of exhaust parts, camshafts, radiator frames, front and rear axles, engine cradles, crankshafts, seat frames, body parts and space frame, sanitary pipes channel having complex shapes.

2. The simulation results have been validated through experimental results and it was observed that thickness along major axis is quite less as compared to thickness along minor axis. Deformation along minor axis is restricted because of less provision of expansion in die cavity and tube wall rapidly came in contact with the internal surface of die wall cavity.

3. By increasing the internal pressure from 30 to 70 MPa, the reduction in thickness increases. The thickness at the start and end point of bulged tube is less as compared to any other points and the reason is high friction factor applied in this region. The transition zone has high frictional coefficient as compared to midpoint of bulge which cause the reduction in thickness in transition zone.

4. The percentage relative error between experimental and simulated thickness reduction increases (approx. 5%) along major axis when internal pressure increases up to 60MPa and relative error reaches approx. 7% for pressure at 70MPa. The percentage thinning along

major axis is quite large as compared to minor axis. The increase in internal pressure along major and minor axis increases the percentage thinning rate.

5. Minimum thickness observed on extreme position (1 and 5) of major axis at 70MPa during experiment is 0.35mm. Simulation results gives 0.41mm thickness. Extreme position (6 and 10) measured minimum thickness of 0.44mm during experiment whereas 0.47mm observed during simulation.

6. A Series of experiments, testing and trials were carried out on die and tooling to develop an experimental tube hydroforming machine set-up. The experiments were performed and measured different bulge heights and corner radii formed in an elliptical tube subjected to various internal pressures and again validated with numerical simulation. It was observed that simulated and experimental data are comparatively matched with each other with a slight deviation. The simulated results show high bulge height achieved early subjected to a defined internal pressure as compared with experimentally obtained bulge height for the same pressure range. The bulge height increases as internal pressure increases and experimentally measured at internal pressures of 30, 40, 50, 60 and 70 MPa as 0.5 mm, 1.25 mm, 1.85 mm, 2.25 mm and 2.5 mm respectively. The simulation results on bulge height are 0.54 mm, 0.65 mm, 1.6 mm, 2.25 mm and 2.5 mm at an internal pressure of 30, 40, 50, 60 and 70 MPa respectively.

7. The maximum bulge height is achieved by conforming to the shape of the maximum undercut cavity provided inside the die of 2.5 mm which is similar for both simulation and experimental. The bulge height of 2.5 mm was achieved through simulation at an internal pressure of approximately 62 MPa whereas experimentally it takes 70 MPa.

8. The corner radius obtained during the experiment is also compared with simulation and it is found that the corner radius obtained through simulation is less than the experimentally obtained results. This is because of ideal friction coefficient taken during simulation is 0.1

and but in reality, the friction coefficient during the experiment is not ideal as we assume during simulation. From experimental investigation, it is observed that the frictional resistance at the contact of tube outer surface and die wall cavity corner radius plays a significant role to get optimum quality of the components or products. Strain hardening is also an important parameter to define material flowability. Strain hardening coefficient has a high influence on the formability of the tube so that for forming of materials with a higher value of n = 0.35 obtained hence Lower internal pressure is needed, but a change in thickness in such materials is higher than in others resulting in lowering of strain hardening coefficient and the friction between die walls and tube increase. The impact of internal pressure on tube hydroforming quality was inspected. During the hydroforming process, the corner radius reduces, and bulge height increases continuously during the rising of internal pressure. Experimentally, the tube sample was completely filled in the die cavity at a pressure of 70 MPa.

9. Mechanical testing of the Al 6061 T4 material has been done. It is observed that ductility characteristics reduces with the increase in tube hydroforming internal pressure but strength is increases due to increase in strain hardening coefficient and is found to be 0.35 at 70 MPa internal pressure.

10. Decrease in roughness of surface of the inner tube wall observed at higher internal pressure. For Al6061, the Surface analysis showed that the surface roughness (Ra) value for surface roughness for undeformed was found to be 0.9925 µm at 30MPa and 0.6915 µm for 70MPa and showing the rise of 9.11% increase in surface finish.

11. Material fails at 73 MPa internal pressure. The critical d/t ratio is observed just before failure at 73 MPa internal pressure is 85.23.

12. FLD curve is plotted for deformed Al 6061 samples at 70 MPa internal pressure. It is observed that sample is safely deformed up to major true strain of 0.15 and minor true strain up to 0.05.

6.2 Scope for future research

1. Testing on alloy tube made up of Titanium and magnesium, Magnesium and Tungsten, aluminium & reinforced carbon fiber matrix are the better future options for producing light weight and high strength products.

2. Experiment can be performed on cryogenic medium.

3. It is possible to conduct experimental research on tubes ranging in thickness from 0.5mm to 2.5mm.

4. study the effect of ultra-high strength materials such as Inconel, 11-10 PH and other precipitation hardened steels can be done using tube hydroforming techniques.

5. Experimental study can be made on different flow rate (MPa/s).

6. The effect of friction between tube samples and sealing may be studied especially when axial feed from sealing ram is in action.

7. A commercial version of Tube hydroforming setup may be developed for industry application.

8. The multi-features bulge tube hydroforming may also be done with this process.