Preface

Tube Hydroforming is one of the most important technologies in modern industry allowing for the production of light but high strength parts such as aircraft structures, car bodies, other structural parts and automotive equipment. It allows obtaining good quality products in a very short time under high internal fluid pressure which is very important to challenge the high competition in the manufacturing market. Tube Hydroforming (THF) has been called with many other names depending on the time and country it was used and investigated. Bulge forming of tubes (BFTs) and liquid bulge forming (LBF) were two earlier terms, for instance. Hydraulic (or hydrostatic) pressure forming (HPF) was another form of name used for a while by some investigators. Internal high pressure forming (IHPF) has been mostly used within German manufacturers and researchers. In some periods of time, it was even called as "Unconventional Tee Forming".

Throughout this paper, THF has been used to describe the metal forming process whereby tubes are formed into complex shapes with a die cavity using internal pressure, which is usually obtained by various means such as hydraulic and axial compressive forces and motion of plunger simultaneously. Application of high strength, low plasticity and difficult-to-form materials for complex-shaped parts makes the conventional tube hydroforming technology face new challenges. "Conventional forming" here means any tube forming process using rigid tools (die, blank-holder and punch). Very often manufacture of structural parts is extremely difficult because conventional forming methods reach their limits.

To overcome problems in conventional tube forming such as stamping, blanking many innovative tube forming techniques have been proposed in the last few decades. A new method called tube hydroforming is introduced by Grey et. al. in 1939.

The principle of tube hydro forming is done by filling of tube using liquid emulsion of a water-soluble material (concentration < 5%) or simple water (which is used in this experiment) after which the tool is closed. The tube is then forced under pressure to adopt the inner contour of the tool by application of an internal pressure and two axial forces provided at tube ends. In some cases, the tube is formed by increasing internal pressure only. In these cases, the axial forces are only so high that leakage is avoided. This means that the axial cylinders do not feed more material into the expansion zone. There are also cases in which the axial cylinders push more material into the expansion zone. In these cases, the tube is formed under the simultaneous action of the internal pressure and the axial forces. The hydroforming operation is either force-controlled (the axial forces are varied with the internal pressure) or stroke-controlled (the stroke is varied with the internal pressure).

In view of above challenges, an attempt is made in present work to exploit and combine the benefits of Hydraulic pressure inside a tube samples. Thus, the internal pressure-based tube hydroforming set up for Aluminium based alloys is conceptualized, designed, developed and fabricated to study the effects of various process parameters such as at different liquid pressure inside tube, thickness distribution, bulge height, corner radius and material mechanical properties variation at different hydraulic internal pressure. The set up predominantly consists of a hydraulic press of capacity Tons, Dies, hydraulic power packs and pressure gauge. The variation in pressure is monitored for each experiment. Extensive experiments are carried out for Aluminium 6061 T4 grade alloy material. The trails are conducted in a sequential manner from designing phase to fabrication and finally successful testing.

In stage I, the experimental machine setup is designed and fabricated. The basic design methodology follows from conceptual design, CAD modeling to final tube hydroforming machine fabrication stage and analytical analysis of dimensions of various die and tooling calculations on the basis of Von Mises-Hencky theory (for ductile even materials; the compressive and tensile strength are approximately same and whose shear strength are smaller than their tensile strength). In stage II, 'Testing of elliptic shape samples are carried out with the help of fabricated tube hydroforming machine setup.' The forming of elliptical bulge tube profiles is investigated with different internal pressures. The procedure follows to bulge the elliptical tube are only with the help of high internal pressure without any side axial feed.

The trials are conducted at different internal pressure range (i) to study the effect of thickness variation with pressure, (ii) to study the corner radius of tube with different internal pressure range and finally (iii) the bulge height recorded with different pressure range. Further mechanical testing of the formed components is done such as 'Stress strain curve for undeformed and deformed samples at high internal pressures, and (ii) to Study the strain hardening pattern. In order to study the surface profile between undeformed and deformed tube samples, (iii) Surface roughness is also carried out.

As Finite element method has become a very reliable and potent tool for virtual simulation process manufacturing thus and expedites the product development cycle, the study on experiments performance using proposed setup. All these are verified numerically using Abaqus FEM software. The effect of internal pressures on tube thickness, the tube corner radius, the tube bulge height and thinning of the component is carried out for symmetrical and non-symmetrical shape geometries. A separate chapter is therefore devoted to FEA studies and results and their validation with experimental findings.

As a summary the thesis on the **"**Development of A Tabletop Tube Hydroforming

Machine: Design, Fabrication & Experiments" has been carried out in the following six chapters.

1. Introduction.
2. Literature review on tube hydroforming.
3. Design and development of a tube hydroforming machine setup and experimentation.
4. FEA studies for elliptical tube hydroforming shapes of workpieces on thickness variation, corner radius and bulge height with different internal pressure range.
5. Experimental study and comparison of elliptical tube hydroforming shapes workpiece on same parameter as discuss above.
6. Conclusion and Scope of Future Work.