Preface

Sheet-metal forming is one of the most important technologies in modern industry allowing for production of light but high strength parts such as: aircraft structures, car bodies and other structural parts, utensils or household equipment. It allows obtaining good quality products in a very short time what is very important because of the high competition in the manufacturing market. Application of high strength, low plasticity and difficult-to-form materials for complex-shaped parts makes the conventional sheet forming technology face new challenges. "Conventional forming" here means any sheet-metal 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 deep drawing, many innovative deep drawing techniques have been proposed in the last few decade. A new method called as Rubber Assisted Forming is introduced by Guerin in 1940. Rubber assisted forming adopts a rubber pad contained in a rigid box acting as a die which uses a single metallic punch. The incompressible elastomer exerts a hydrostatic pressure on the sheet metal by deforming at constant volume. As the punch advances, the rubber behaves like a hydraulic fluid pad that exerts equal pressure throughout the surface of the workpiece when it is pressed by block or punch. The multidirectional nature of the force from the rubber pad produces variable radius during forming and thus enhances uniform elongation of the workpiece. The process exploits the benefits of flexible rubber punch and produces the complex shaped sheet metal components with minimal spring back and profile deviation. Parts with excellent surface finish can be formed with no tool marks and severe variations in the metal thickness, as occurs in conventional forming processes, is reduced considerably. The main purpose of these processes are to enhance the limiting drawing ratio, releases the component from the fracture to minimize the variation of the thickness of drawn cups and to reduce the cost of tooling especially for irregular geometry.

Some of the very popular processes under Rubber-pad forming are Guerin process, Marform deep drawing process, Verson Hydroforming process, SAAB rubber diaphragm process and Maslennikov's process.

Sheet Hydro-forming is another powerful method of fabricating the sheet metal components. In this process, the solid die cavity is replaced with hydraulic fluid contained in die chamber. The fluid is pressurised to a given pressure which exerts hydrostatic pressure on the component during drawing operation. Thus this process is very much similar to rubber assisted forming. However, fluid being incompressible and non-elastic poses problems of maintaining same pressure during forming operation. Rubber being an elastic material provides extra support especially for very complex features such as sharp cones, miniature projections etc.

In view of above challenges, an attempt is made in present work to exploit and combine the benefits of Hydraulic back pressure and elasticity of rubber diaphragm. The rubber based hydroforming set up is conceptualised, designed, developed and fabricated to study the effects of various process parameters such as blank holding force, hydraulic back pressure and hardness of rubber. The set up predominantly consists of hydraulic press of capacity 20 Tons, Dies, Load cell, hydraulic power packs, data acquisition system and pressure transducers. The online variation in pressure and load are monitored for each experiment.

The experiments are carried out for stainless Steel 304 grade alloy and pure copper material. The trails are conducted in a sequential manner. In stage I, the trials are carried out to evaluate the case of 'Shallow Forming' (H/D<0.5). In stage II, 'Deep Drawing' profiles such as cones and hemispherical profiles are designed and fabricated. The trials are conducted for both 'conventional forming' and 'rubber assisted forming' and comparative study of thickness variation along the profile, microstructure variation and hardness variation are presented in the thesis. Further comparative 'Formability Study' of both the processes are carried out using 'grid technique'. The major strains and minor strains are measured and plotted against 'Forming Limit Curve' (FLC) of the pure copper. In order to study the effect of different materials of rubber diaphragms, three varieties of rubbers viz. Natural rubber, Nitrile rubber and Silicone rubber are manufactured keeping the same shore hardness. The hemispherical cup is drawn separately under these three rubbers and formability study is carried out in terms of 'percentage thinning'. As Finite element method has become a very potent tool to virtually simulate the manufacturing process and expedite the product development cycle, the experiments performed using proposed setup are verified numerically using Abaqus FEM software. The effect of friction, blank holding force and rubber hardness on Von-mises stress, plastic strain and thinning in the component is carried out for symmetrical and non-symmetrical shapes. A separate chapter is therefore devoted on FEA studies and results and their correlation with experimental results.

As a summary the study on Rubber based sheet hydroforming process has been carried out in the following manner:

1. Literature review on deep drawing, rubber pad forming and sheet hydroforming
2. Material characterisation for materials such as stainless steel 304 grade, pure copper and rubber diaphragms.
3. Design and development of a rubber based sheet hydroforming set up and experimentation
4. Experimental trials for shallow forming and deep drawing using proposed setup.
5. Formability study of the workpieces using grid technique
6. FEA studies for symmetrical and non-symmetrical shapes of workpieces/ product.