ABSTRACT

Metal Forming Process (MFP) is the imperative backbone of current manufacturing industry. MFP is the process of converting the raw material in to finished product by plastically deforming the metal into the required shape or geometry by the application of force. MFP is partitioned as two major groups namely bulk forming process and sheet MFP. Sheet metal operations like bending, drawing, shearing, blanking, punching are mostly carried out in presses using a set of tools called as die and punch.

Metal Spinning Process (MSP) and Incremental Sheet Forming Process (ISFP) provide an alternative method for manufacturing low-volume functional flexible sheet metal products. In these two processes, the parts were formed by creating localized plastic deformation on the blank by either forming tool or forming roller, which moves with the aid of Computer Numerical Control (CNC). In MSP, the required shape is formed by combining the rotational motion of blank and forcing the tool against the blank. In ISFP, the parts are formed by combining the linear motion of the blank and forcing the rotating tool against the metal blank. The major process defects of ISFP were geometrical accuracy of finished parts, difficulty in manufacturing parts having the wall angle nearer to 90° or above 90°, cracks, high process time and poor Surface Finish (SF). Due to the local metal blank deformation, wall thickness variation and defects related to thinning were seen in ISFP and MSP. On the other hand, the MSP had issues related to cracks, wrinkling failure and SR. With these issues, the application of ISFP and MSP were confined to manufacturing parts that possess asymmetric profile. But with the advantages possessed by MSP and ISFP such as lesser forming load and inexpensive tooling with small-batch production, these two forming processes have undergone a renaissance in recent years.

To overcome the drawbacks of MSP and ISFP, and to improve its advantages, a new Hybrid Profile Forming (HPF) process is designed and investigated. This process combines the advantages of ISFP and MSP, with the objective of forming hollow axisymmetrical parts without employing expensive and dedicated machinery, mandrels and forming tools. In this hybrid process, the rotation of metal blank concept from MSP and the die-less sheet metal forming concept from ISFP are combined. With this process, hemispherical, hemi-ellipsoidal and hemi-epicycloidal shaped parts are formed by employing cold rolled low carbon steel sheet of thickness 1.6 mm as forming material. Here, the necessary tool path is achieved by the longitudinal (x axis) and cross wise (y axis) movement of a roller holder.

To further improve the quality of parts formed by HPF process, an additional rotational movement of the tool holder about its vertical axis is incorporated. A novel tool holding equipment is manufactured. This new process is termed as Improved HPF (IHPF) process. Similar to the HPF process, the same three shapes are with the aid of IHPF process.

In both HPF and IHPF process, the metal forming is achieved by the rotational motion of the blank at constant speed and the roller forcing the blank to deform locally to a defined axisymmetric shape. These processes are accomplished through two-axis and three-axis CNC machines. Servo motors were utilized to numerically control the tool motion. Furthermore, the desired tool path is directly drawn in CAD/CAM software and the CNC codes were obtained from the drawn tool path and transmitted to the CNC machine as a CNC code. In both the processes, the combinations of inward and outward tool movements are used. The hemispherical shape is formed using a combination of straight line and circular tool path. In a similar manner, straight line and elliptical tool paths are used for hemi-ellipsoidal shapes and, circular and epicycloidal tool paths are used for hemi-epicycloidal shapes.

The formed parts are cut into 20 X 20 mm sized pieces with the aid of a wire cut machine. The cut samples are marked with various zone numbers for identification. The first zone of the part was clamped by the blank holding fixture which prevents the deformation of the blank during forming. Due to this reason, the first zones in all parts are eliminated from the analysis.

The chemical composition, hardness, Microstructure (MS), Surface Roughness (SR) and Forming Limit Curve (FLC) of Extra Deep Drawing Steel (EDDS) sheet is initially obtained through testing. In the analysis of HPF and IHPF process, the thickness variation, hardness, MS, SR and forming process time are measured and analyzed. It has been observed that as the depth of the formed part varies, the thickness also varies. Also, the SR increases proportionally with the increasing in percentage of reduction in thickness. In all the zones of the formed part, the surface strains are in tension-tension conditions and there is no tension compression and plane strain condition observed. Due to this reason wrinkles failure is eradicated in both HPF and IHPF process. Furthermore, the forming process time is minimized in IHPF process compared to ISFP, by integrating ISFP and MSP for shallow axis-symmetric components and accomplishing pliability without utilizing costly machinery, mandrels and forming tools. It is inferred that IHPF process is superior to HPF, MSP and ISFP process in terms of thickness variation, lesser strain and lesser springback of formed parts.