ABSTRACT

The reported revenue of sheet metal industry is 21.6 billon USD, with an estimated gross profit of 22.97% during the year 2014–2015. Sheet metal applications are widely used in automotive, aerospace, biomedical, construction, and communication industries. Conventionally, press tools are used for sheet metal forming (SMF) using dies and punches. The shape of the final product depends on the dimensional accuracy of the die and punches. There is a limited flexibility in manufacturing due to the higher tooling costs of die and punches and the greater lead time for even minor modification to suit the dynamic behavior of the industry. Hence, the conventional manufacturing method is highly suitable for mass production only.

To address the dynamic customer requirements, several researchers have worked on incremental sheet forming (ISF) process, which utilizes a simple tool with a great attention. This method is an economic process especially suitable for customized and low volume production. Single point incremental sheet forming technology is a flexible process in which a sheet of metal is formed by a progression of localized deformation. This process is flexible because a simple generic tool moves over the surface of the sheet to cause deformation due to highly localized plastic deformation, unlike in conventional process, wherein specialized tooling such as punch and die is required for SMF. Hence a wide range of different shapes can be formed by moving the generic tool along a defined path of the required geometry.

The aim of this research is to study the effects of process variables and to optimize the process parameters of single point incremental forming (SPIF) to minimize the springback effects of a sheet metal product and to minimize the process time.

Experimental work has been carried out for producing complex shapes in the sheet metal parts from aluminum alloy (AA 1050) and verified by numerical methods. Experiments are carried out to produce four different parts of varying shapes and complex geometries such as cup, bowl, cone, and shell parts.

Research on advanced methods of SMF expands the capabilities of SPIF technologies to produce parts from Al, Mg, and Ti alloys, super alloys as well as ultra-high-Speed steels. These materials have great potential to be used in aircrafts, aerospace, automobile, defense, electronics, and medical equipment. In this work, the forming conditions of aluminum alloy (AA 1050) using the SPIF process are investigated.

The process parameters such as thickness of the sheet, forming tool diameter, vertical step, feed rate, and forming tool rotational speed are investigated and optimized using Design of Experiment (DOE), Taguchi Method’s L27 orthogonal array.

SPIF experiments were conducted using a Computer Numerical Control (CNC) machine, forming tool of High-Speed Steel (HSS)-grade with a hemispherical head and customized fixture with a clamping system. DOE is used to plan the series of experiments on aluminum alloys sheets. The significance of various process parameters and their influence on responses such as thickness reduction, springback, hardness, and roughness of the product is carried out by Analysis of variance (ANOVA).

Springback in the component is measured using a dial gauge of 1 micron accuracy. As the deformation during SPIF is mainly plastic, a simple hardness test is performed using the Brinell hardness device to study the influence of metal hardness and variation in the mechanical properties of the finished product. Moreover, the roughness of the surface of the formed products is measured using a roughness measuring instrument.

Numerical analysis of the SPIF process is conducted using the commercial finite element (FE) codes ABAQUS and PAM-STAMP. Based on the experiments and numerical analysis, greater confidence in the SPIF process can be achieved with best optimized processing time and better geometrical accuracy.

The experiments demonstrated the ability to form complex shape parts and the numerical analysis with commercial codes predicted the springback characteristics very well. The results obtained from this work will be useful for forming aluminum alloys using the SPIF process.