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Development of Single Point Incremental FormingProcess on CNC Milling Machine Using 3D Printed Fixture Arrangment

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Abstract: *There are many forming processes, being used in the global market for a long time. Many conventional sheet forming processes are tedious, time taking in design and development of punches, dies and costlier. In order to solve these problems single point incremental forming process is introduced which is modern method for sheet forming for prototypes, customized parts and small size batch products.The SPIF (single point incremental forming) process is a flexible process which does not need dedicated tooling and dies. This paper presents the design of fixture arrangement in CATIA, static structural analysis is done using Ansys 14.5 to determine the deformations produced in the fixture during forming. The designed fixture arrangement is fabricated using 3D printing process. Here the deformed tools with hemispherical shapes are used. Aluminum alloy 6061 sheet of 0.5 mm thickness is used for current experiment study. Screen printing technique with circular grid marking is used for measuring strains. These strains are used for constructing Forming limit curves of aluminum alloy. Entire work is done by forming cone shape using CNC milling machine for measuring strains in the final geometry. DOE has been used to study the effect of forming parameters such as tool diameter, step size, feed rate and spindle speed on forming limit curves.Single point incremental forming process is used to form a cone shape and deformed circles on the sheet blank will measure the major and minor axis lengths. Using these values major and minor strains are calculated and FLC curves are drawn to study the behavior of sheet blanks.Finally comparison is done for all 27 experimental runs.*

Keywords: *CATIA, static structural analysis, 3D printing, PLA, screen printing and forming limit curves.*

I. INTRODUCTION

Materials are converted into final products by using different manufacturing methods. The mostly used manufacturing process in many industrial fields and civil sectors is sheet metal forming and which is capable to produce good quality parts. In this process sheet is changed to required shape by using punch & dies combination. In CSF designing the tooling& die is very complex and difficult, because the punch & die need to design and manufacture for each component which is costlier. Due to this economic competitiveness and need of complex shapes the manufacturing industries must find new methods that are more flexible and also satisfy the different customers & market needs. To meet demands of customer needs new methods called ISFM have been developed. It is one of the flexible processes, in which the sheet is deformed by a localized deformation. This localized plastic deformation occurs step by step giving incremental feed to the deformed tool. Flexible means no specialized tools & dies are required. A simple tool is enough for deforming sheet into final product, which is having higher forming limits compared to CSF processes. The basic SPIF process consists of fixture arrangement (blank holder) for holding sheet during the process, and deformed tool for forming the shape according to the program given through the computer and sheet blank material and CNC machine for performing the operation.

II. LITERATURE REVIEW

Vishal et al (2017) investigated some of the process parameters on forming forces developed during SPIF process on AA6063 aluminum sheets using table type dynamometer. This process is suitable for producing small scale production to deal with the various customization parts and prototypes. SPIF is carried to get the responses for forming forces [1]. Nimbalkar D.H (2013) mentioned review on incremental sheet forming of sheet metal components and the current state of incremental sheet metal forming process[2]. Jigar Patel et al (2015) focused on design and analysis of flexible fixture for SPIF process. Fixture is one of the main component in the SPIF process, which holds, supports and

clamps the sheet blanks and almost reduces the costs related to dies and punches and having more flexibility in clamping and unclamping of the backing plates and work pieces [3].Yogesh K. et al (2015) worked on design and development of SPIF process. A laboratory setup of IFM has been developed and CAD model of blank holder arrangement is done. A brass sheet blank is used to develop a cone shape with the dimensions of 40 mm outer diameter and 20 mm inner diameter successfully without any defects [4]. Ritesh Thakur et al (2015) worked on optimization of surface roughness and profile accuracy using SPIF process. This paper explains about the systematic approach of modeling and optimizing the effect of three input parameters as step depth, tool diameter and feed rate. The experiments are conducted on AA1200 H14 aluminum alloy and analyzed by using RSM with box-behnken design [5]. Sundarasrinivasan.A et al (2015) focused on experimental study of stainless steel 316 (AISI) 0.8 mm sheet for truncated pyramid by using SPIF process. In this research work the parameters were examined using pyramid size of 100mm×100mm×55mm. For determining the optimum conditions DOE with Gray multi responses optimization used with L_9 OA. The response study was performed on average surface roughness, time and accuracy of the process [6]. V.Mugendiran et al (2014) presented comparison of FLD & thickness distribution on AA5052 1mm thickness has done by using SPIF process. Here formability analysis is done to obtain the better forming process. In this experimental work Forming limit curves for truncated square pyramid and cone shapes developed, and comparison is done for both the shapes [7]. Fahrettin Ozturk et al (2009) mentioned types of grid markings, methods for grid marking and measurements for grid markings are explained. Grid marking is one of the methods for measuring the deformations for determination of major & minor axis lengths. These lengths are used for calculating major and minor strains, with the help of these strains Forming limit curve is drawn between major & minor strains [8]. Venugopal et al worked on development of 3D printed jigs and fixtures using FDM technique in M.tech thesis 2016 [9].Joost Duflou et al (2007) conducted experimental study on force measurements for SPIF process by considering step size, tool diameter, wall angle and thickness of the sheet [10].Varthini.R et al (2014) reported in their research work modeling and optimization of process parameters of SPIF process on AA 5052 using genetic algorithm and Back propagation neural networks. The main contributions of this work to SPIF was the successful manufacturing of a cone shaped components by considering the vertical step size, lubrication, feed rate, spindle speed and tool diameter [11].

III. ELEMENTS OF SINGLE POINT INCREMENTAL FOMING PROCESS

A. Fixture Arrangement:

Here the fixture arrangement is designed by using CATIA software, and it consists of cylinders, supporting and base plates. The base, supporting plate dimensions are of 140mm×120mm×10mm, 90mm×100mm×7mm, and these are fabricated using 3D printing process. Finally all the components are assembled to get the fixture arrangement.

B. Deformed tool(Single point hemispherical tool)

The deformed tool is hemispherical shape and the material used for manufacturing of the tools are stainless steel.Here in this present work tools with different tip daimeters of 4,6 and 8mm with total 60mm length are used.

C. Sheet blanks

The materials selected for this work is Aluminum alloy 6061 with 0.5mm thickness.Aluminum alloy of blank size 90mm×100mm×0.5mm has been used for current experimental study.

D. CNC milling machine

The shape of the component is developed by using Single point incremental forming process with the help of MTAB XL Mill CNC milling machine. Here the tool moves according to the pre-defined path and results the final shape.

IV. MEHTODOLOGY

- Design of Fixture Arrangement
- Static structural analysis of Fixture Arrangement
- Fabrication of Fixture Arrangement using 3D printing
- Design of Hemispherical tools
- Manufacturing of Hemispherical tools
- Procurement of Aluminum alloy sheets and Preparation.
- Screen printing process for grid marking
- Selection of shape & tool path
- DOE using Taguchi method

- SPIF using CNC milling Machine
- Measurement of Strains using tool maker's microscope and with the help Mylar tape.
- Constructing Forming limit curves

V. EXPERIMENTAL SETUP

In Single point incremental sheet forming process, methodology of deforming the sheets plays very critical role. The tool path is generated in computer numerical control (CNC) milling machine and is utilized to form progressively the sheet into a component. During the process there is no backup die supporting the back surface of the sheet. This SPIF process is capable of producing 3D complex components.

Fig.1 Experimental setup using CNC milling machine

The fixture holding arrangement consists of 9 parts. This consists of 6 cylinders, one top plate, one middle plate and base plate. All these parts are designed by using CATIA V5 R20 software according to the working area of CNC milling machine. Static structural analysis is carried out using Ansys 14.5 to find out the deformations produced during the forming process. The maximum permissible deformation induced during the forming is 2.09 mm, according to this deformation the step size is selected.

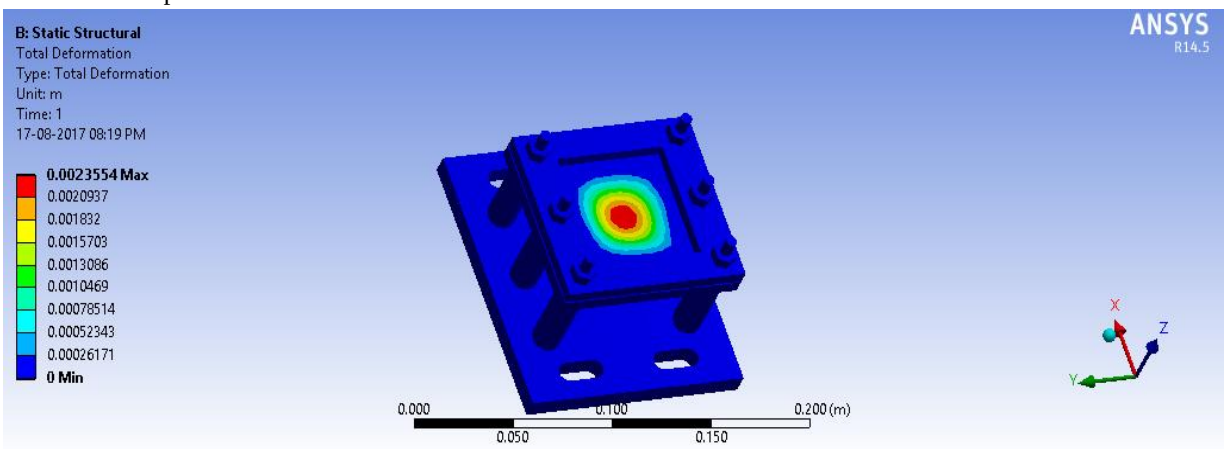


Fig.2 Static structural analysis of Fixture Arrangement

The designed fixture assembly is fabricated using 3D printing process. Here the material used for 3D printing process is PLA (Poly Lactic Acid). This material is very easy for printing the prototypes and no heating of the bed is required.

Fig.3 3D printed Fixture arrangement

Hemispherical types of forming tools are used in this experimental work and the material used for manufacturing forming tool is stainless steel. Deforming tools of 4, 6 and 8mm of different tip diameters are used for measuring the formability. Circular grid type of screen printing process is used for grid marking with 3mm circle diameter on the sheet blanks for measuring the major & minor strains induced during the forming process. These circles will deform into ellipse of different shapes, by using the tool maker's microscope and with the help of Mylar tape major and minor axis lengths are measured. Using the formulae major and minor strains are calculated. The dimensions of 45mm top diameter, 7mm bottom diameter are taken for the formation of cone shapes using single point incremental forming process.

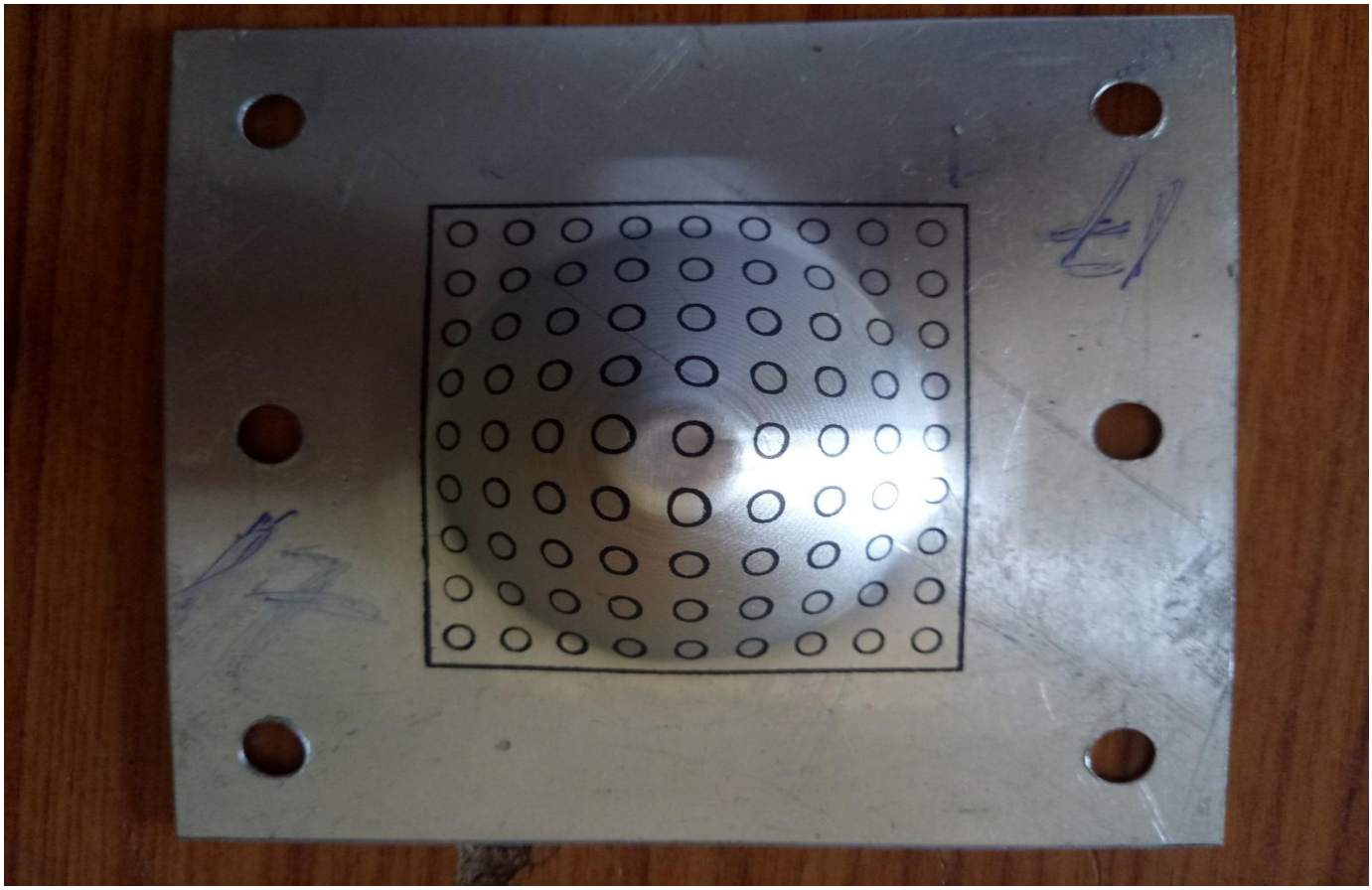
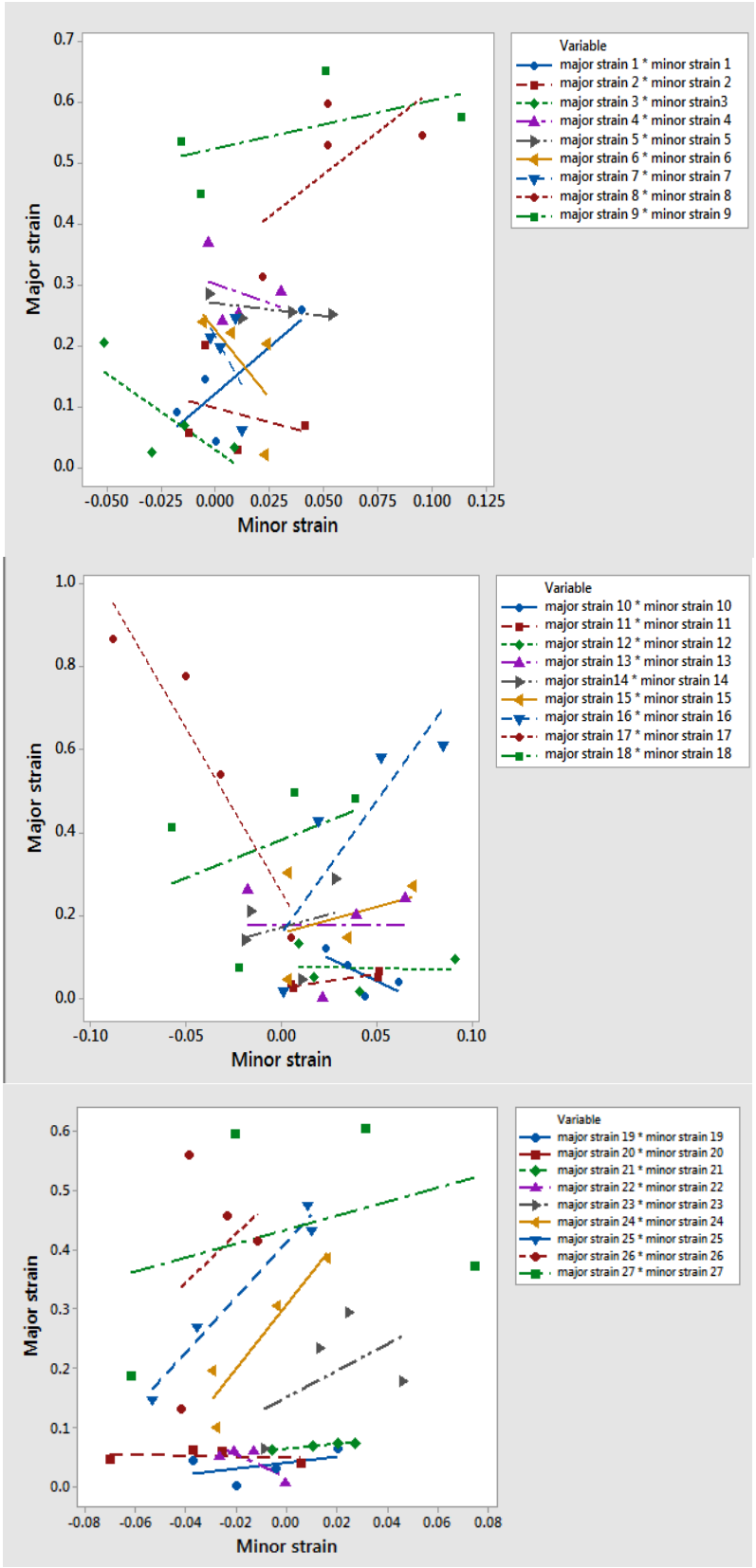


Fig.4 Cone shape using SPIF process

VI. RESULTS& DISCUSSION

Major and minor strains are calculated for constructing forming limit curves for all 27 experiment runs. After calculating all the strains forming limit curves are drawn by taking major strain on Y-axis and minor strain on X-axis respectively. Forming limit curves are drawn for all 27 experimental runs, and the graphs are shown in graph below.



Graph1.Forminglimits curves for 1-27 experimental runs

VII. CONCLUSION

Forming limit curves are constructed for all 27 experimental runs and the maximum formability is observed at tool diameter 8mm, step size 0.6, feed rate of 100mm/min and 2000 rpm spindle speed and minimum formability of the AA 6061 sheet with 0.5mm thickness is observed at tool diameter 8mm, step size 0.4, feed rate of 50mm/min and 2000 rpm spindle speed. Maximum and minimum major strains induced during the SPIF process are 0.866mm, 0.0066mm respectively. Maximum, and minimum minor strains induced during the SPIF process are 0.114mm, -0.088mm respectively. Nature of the strains induced are both compressive and tensile.

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