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A Review Paper on Optimization of process Parameter in Incremental Sheet Forming of Al7050 using Taguchi Analysis

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Abstract

The aim of this paper is to review the Taguchi method to find the best process parameters and improved quality results of incremental sheet forming (ISF). Taguchi technique is used to investigate the variation in number of experiments, parameter and focus on acceptance in improving man-made quality. The highest possible performance of parameters is obtained by determining the optimum combination of design factors by this technique. The present work focused by using L 9 Orthogonal Array (OA) on the processing steps to get the optimal values by conducting machining on CNC machining, and Analysis of variance (ANOVA) will employed to investigate the characteristics and experimental results which will provide the effectiveness of this approach. This technology has met the current needs of industry for making prototype and model especially owning to its shorter design cycles and improved the design of quality.
Keywords: Step depth, Tool speed, Cone angle, Sheet thickness, Taguchi Analysis

I. INTRODUCTION

The basic principle of incremental sheet metal forming on CNC can be described as follows: the forming tool moves around the outline of the part to be formed along the predefined tool path where sheet metal is fix in the attachment which is mount on the CNC table and a hemispherical tool extrudes the sheet metal point by point so as that the local plastic deformations are occurred and the sheet metal forming is realized incrementally. It is obvious that the sheet metal forming is realized by the tool extrusion movements around the outline of the part to be formed, so the tool paths that are used for controlling the tool movements have a great effect on the dimensional accuracy, surface quality, and forming time. Therefore, how to generate an efficient and reasonable tool path, step depth, tool speed, cone angle, and sheet thickness by fully considering the features of the CNC incremental forming is one of the most important research problems of the CNC incremental forming technology.

The conventional sheet forming process is performed with the help of dies and lathe. Its basic requirement is that the production volume of the product is large; otherwise the cost will be too high. However, the recent market requirements for products tend to vary quickly and to be of small volume, so the conventional sheet forming process with dies is not satisfactory. In order to adapt to the changing requirements of the market, the conventional process must be improved to form a flexible manufacture mode.

The CNC incremental sheet forming process is a flexible forming process, in which the NC program is designed according to the forming requirement of the sheet, and then a spherical-head tool forms the sheet step-by-step according to a certain locus by the feed system of the CNC machine, required shape being satisfied. This forming process does not need dedicated forming dies. It can adjust the forming locus of the spherical-head tool by correcting the NC program to control the shape of production. Thus, its forming period is short and changes in production are fast. It can form a complex surface. This process is very well suited to the small volume, varied, complex production of plate and prototype. The CNC incremental forming process has attracted increasingly more attention recently. The main characteristics of this process are: the sheet is formed according to a given locus; the deformation of the sheet is point-by point; and the deformation of every step is small. In theory, the incremental forming process can control the deformation of any point in the sheet and even the degree of sheet deformation. Thus, for the incremental forming process, the key problem to solve is the selection of the deforming order and the degree of deformation in every step, i.e., the optimization of the forming locus.

A. *Step Depth:*

It is the feed given to CNC tool in z-direction to the layer being deformed in a single pass from the work piece. The excessive step depth may cause shear failure of the work piece or sheet metal. In figure (1) difference between z-coordinate in position 1 and 2 shows the step depth.

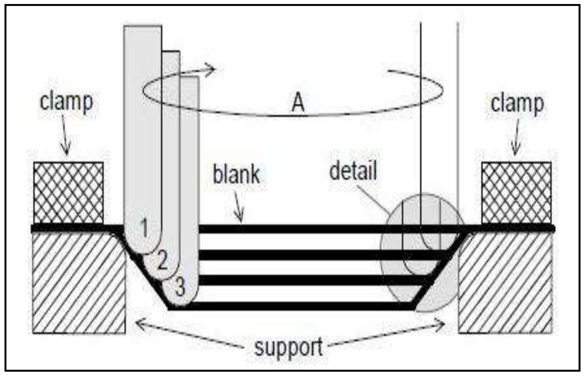

Fig. 1:

B. *Tool Speed:*

It may be defined as the rate or speed at which the tool rotates in revolution per minute (rpm) or meter per minute. Higher the tool speed leads to low processing time which make incremental sheet forming an efficient method.

C. *Cone Angle:*

It is the angle made by slant length with its top line as shown in figure (2) by alpha. In materials having low ductility or poor forming properties cone angle more than specified vale may cause shear failure of the work piece.

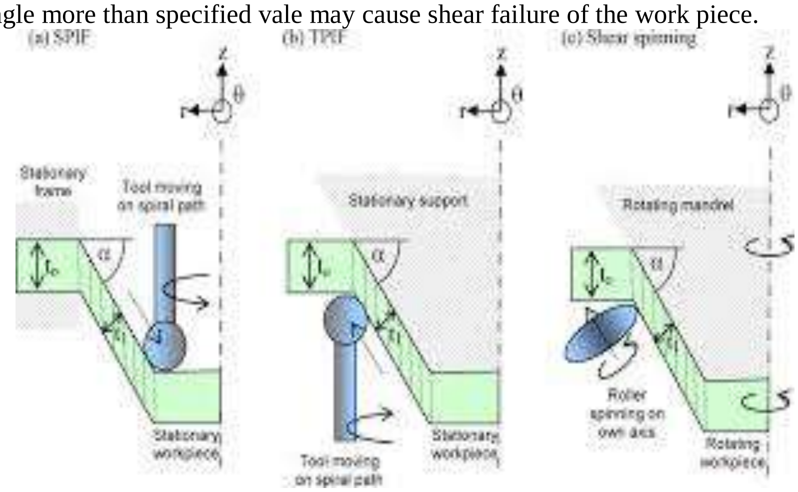

Fig. 2:

D. *Sheet Thickness:*

Thickness of sheet metal as shown in figure-2by 't_0' reduce during incremental sheet forming process(t_1 as shown in fig.-2) which is caused by plastic deformation of work piece. It can be measured in mm by using venire calliper or screw gauge.

II. LITERATURE REVIEW

K.A. Al-Ghamdi et al. (2015) [1]study the influence of small tool radii on the formability (θmax) is identified for single point incremental forming (SPIF). The relative value of tool radius and blank thickness (i.e., R/Tb, where R is the tool radius and T is the blank thickness) was varied over a range (from 1.1 to 3.9), and a formability diagram in the R/Tb-Q_{max} space was obtained. It is observed that there is a critical radius of tool (R_c) that maximizes the formability in SPIF. This radius which was found to be independent of the material type (or property) is a function of blank thickness related as, R=2.2Tb.

Dongkai Xu, Bin Lu et al. (2014) [2] In this work, two heat-assisted ISF approaches, frictional stir- and electric hot- assisted ISF, have been employed to process the hard-to-form materials in terms of the flexibility and local dynamic heating. The temperature evolution and corresponding forming force at different feed rates of these two techniques, is investigated in detail to build up a processing window. In addition, process capabilities are compared by forming different geometrical shapes of magnesium alloy AZ31B of 1.4 mm sheet thickness. The investigation results show the pros and cons of frictional stir- and electric hot- assisted ISF. Frictional stir assisted ISF is more efficient than electric hot-assisted ISF under current experimental results.

As compared to electric hot-assisted ISF with current of 500 A, frictional stir-assisted ISF with tool rotation of 5000 rpm can successfully form the truncated funnel shape at a higher feed rate. According to current experimental results, it may be concluded that frictional stir-assisted ISF has higher processing efficiency than electric hot-assisted ISF.

B.Taleb Araghi et al. (2014) [3]A new hybrid process was investigated by araghi in which accumulated die is used on one side of the sheet and tool deform the sheet in prescribed path projected on die. The combination of AISF(accumulated incremental sheet forming) and stretch forming was put forward. A noticeable reduction of production time was observed by Araghi. In AISF a more uniform thickness distribution is achieved.

Rakesh Madhukar Shendage, Sharanappa Madagonda Pujari (2014) [4] Formability of sheet material was predicted from a tension test. Theoretical forming limit diagrams which were constructed using Levy-Mises flow rule for plastic deformation. Rotational parts i.e. frustum of cone were formed by incremental method using 3axis CNC machine. L9 model was selected using design of experiment by Taguchi method which gave 9 experimental runs to be conducted. Three process parameters considered were tool diameter, vertical step size and feed rate. Responses measured were fracture depth and thickness distribution. The most influencing parameters and there percent contribution to response is calculated using ANAOVA statistical models.

The last column of the above table indicates the percentage of contribution (%P) of each factor, thus exhibiting the level of influence on the quality characteristics. The Table 4.3 shows tool diameter, steps size and feed rate have percentage contributions of 84.86, 9.09 and 3.04 on the final thickness of sheet blank respectively. The last column of the Table 6 indicates the percentage contribution (% P) of each factor, thus exhibiting the level of influence on the quality characteristic. The Table 4.5 shows that the tool diameter, step size and feed rate had percentage contributions of 0.63, 97.49 and 0.19% on the fracture depth of frustum of a cup respectively

M.C. Radu et al. (2013) [5]They study the effect of following parameters on surface roughness and microstructure found that High values of tool diameter have positive effects on surface roughness and microstructure of parts but negative effects on the parts' accuracy. The tool vertical step has positive effects on the three analyzed characteristics of quality as long as it has small values. High values of the feed rate lead to a finer surface and to a refined microstructure of parts but, in general, to a low-dimensional accuracy. High values of the spindle speed have a positive influence on the accuracy, surface roughness, and microstructure of parts.

M. Skjoedt et al. (2013)[6]They observed that it is difficult to make cup shape in single step depth sometimes it results shear failure of sheet metal. The multi stage strategy presented is able to produce a cup with a 90° drawing angle which has not been possible before. The distribution of strains is not only depending on the geometry of the tool path but also on the direction (downwards or upwards). The proposed strategy needs to be refined by further research but presents a promising concept for forming parts with vertical sides in SPIF.

Maria B. Silva & Peter S. Nielsen & Niels Bay & P.A. F. Martins(2011)[7]This paper revisits failure in SPIF and presents a new level of understanding on the influence of process variables such as the tool radius that assists the authors to propose a new unified view on formability limits and development of fracture. The unified view conciliates the aforementioned different explanations on the role of necking in fracture and is consistent with the experimental observations that have been reported in the past years. The work is performed on aluminium AA1050-H111 sheets and involves independent determination of formability limits by necking and fracture using tensile and hydraulic bulge tests in conjunction with SPIF of benchmark shapes under laboratory conditions.

Hu Zhu &Zhijun Liu &Jianhui Fu (2010)[8] The method for the spiral tool-path generation with constant scallop height was proposed based on the triangular mesh model according to the characters of sheet metal CNC incremental forming, and the software system was developed. The proposed method can automatically generate the spiral tool path with constant scallop according to the given parameters, and the software system runs steadily and reliably. The generated spiral tool paths are continuous and smooth and make the whole forming process even and continuous so that the surface quality can be improved.

Attanasio et al. (2009) [9]They did research aimed at improving the knowledge of two point incremental forming with full die. They study the influence of tool path on processing time and formability. The spiral tool path in symmetric shape products like cup or cone shape reduces processing time and raise geometric accuracy as well as surface roughness. In particular, the selection of the tool path design in sheet incremental forming has great effect on efficiency of incremental sheet metal forming process.

G. Hussain & L. Gao& N. Hayat & N. U. Dar (2009) [10] The formability of AA-2024 sheets, an aerospace grade material, in the annealed and pre-aged conditions has been investigated in the single-point incremental forming (SPIF) process. The major operating parameters, namely step size, tool radius, and forming speed, of SPIF process were varied over wide ranges, and their effect on the formability was quantified through a response surface method called as central composite rotational design. It was found that the interaction of step size and tool radius is very significant on the formability.

The optimization criteria used was as follows: r = in range, p = in range, f = maximize, and θ_{max}= maximize. The following solution after undergoing several iterations was recommended by the Dx-7 software: r=4 mm, p=0.36 mm, and f=4,500 mm/min. This combination of the process parameters is believed to provide 69° θ_{max} provided that the other forming conditions remain unchanged.

Julian M. Allwooda, Daniel Braunb, Omer Musica(2009)[11]

Geometric accuracy has been a key concern for developers of the incremental sheet forming process since its inception. Allwood et al. report that industrial users of sheet forming processes typically specify geometric tolerances of around ±0.2mm over the whole surface of a part, and yet the performance of incremental sheet forming processes is typically more than 10 times worse than this. In fact, three definitions of geometric accuracy can be given for this process, each of which has progressively worse tolerance:

- Clamped accuracy – is defined relative to the geometry of the part when still clamped within the blank-holder of the process. This is what would be 'seen' by on-line measurement of part geometry.

- Unclamped accuracy – is defined relative to the part when it has been released from the blank-holder, and is typically significantly worse than the clamped accuracy due to residual stress created in the process.
- Final accuracy – is defined relative to the part when it has been cut out from the unwanted material of the blank. In some cases, cutting out a shallow dish part can actually lead to a loss of all apparent curvature created while the part was clamped.

III. CONCLUSION

From the above research paper we found that most of the researchers had taken various forming strategies like single point incremental forming, two point incremental forming, accumulated incremental sheet forming, heat-assisted ISF approaches, frictional stir- and electric hot- assisted ISF to study the different parameters by their experimental work but taguchi optimization technique is not used by them. Finite element method is also used by many researchers which gave accurate result for specified parameters but this is not a practical approach. The beauty of taguchi technique is that we can derive results for different number of experiment by performing minimum number of experiment and mo0re than one parameter can be optimized using this technique. By studying the above literature we concluded that step depth, cone angle, spindle speed and sheet thickness are the most significant parameters and taguchi is quiet systematic and efficient approach for optimization of above parameters.

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