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Analysis of Formability in Incremental Sheet Forming of Aluminum Alloy AA1100

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***Abstract*— Non-corrosiveness and lightweight are the characteristics of aluminium due to which it is finding wider application in industries. However, forming aluminium sheet is difficult as compared to steel. Thus, emerging methods like incremental sheet forming in which formability is higher as compared to conventional method must be used for the purpose. Also with increasing demand to custom made products and extensive use of prototypes in new product development, Incremental Sheet Metal Forming (ISF) is gaining higher and higher attention due to use of part independent tooling and ability to form custom made part economically. In the current experimental work, effect of four forming parameters namely step size, wall angle, feed rate and rotational spindle speed is analysed for formability of aluminium alloy AA1100. It was found that, formability is mainly affected by the wall angle. Lower feed rates are advisable for higher formability. The different modes of cracking revealed that the formability in the process is limited by necking as well as through thickness shear in the component which is due to serrated strain path resulting from cyclic plastic deformation.**

Keywords: Incremental sheet forming, Taguchis Experimental design, Formability, Aluminium.

I. INTRODUCTION

Sheet metal forming is one of the most extensively used manufacturing processes for the fabrication of a variety of products in many industries. The conventional sheet metal forming process need part dependent tooling, which costs in terms of time and money. Due to these factors, along with increasing variants, variety in the sheet metal fabrication, forming processes with high flexibility are being developed. The incremental sheet forming (ISF) is one of the emerging flexible forming technologies in the sheet metal engineering. The process setup is very simple. The forming tool is a rod with a spherical end. The sheet is mounted in a rig which allows forming of the sheet into the cavity of the rig. Below the sheet a supportive backing plate can be used to get a clear definition of the transition between the flange part and the formed part. SPIF is also called a die-less forming process since all information about the geometry comes from the path of the forming tool. In other words, no dedicated dies are being used. The tool path is controlled generally by a CNC machine and the tool imposes a series of local deformation on sheet. It is the result of these small deformations that a sheet is completely formed to required shape. Incremental sheet forming has demonstrated its great potential to form complex three dimensional parts without using a component specific tooling. The die-less nature in incremental forming provides competitive alternative for economically and effectively fabricating low volume functional sheet products

II. LITERATURE SURVEY

A considerable work has been done into this field of ISF. Surface roughness modelling can be done with different techniques as artificial neural network, support vector regression and genetic programming. However, the genetic programing model is in better accordance with experimental results as compared to others. [2]As a critical quality constrain, Surface finish is regarded as weak point for ISF process. Thus, it is of great importance to identify effect of process parameters on surface roughness and optimize surface roughness for production requirements. [3]The geometries produced by ISF represent some errors along the oblique walls. In particular, a sort of distortion is also obtained, generating a curvature on the expected straight sides. This phenomenon is due to elastic spring back whose effect is lower in correspondence of the edges, where the geometrical stiffness is higher than in other areas. The accuracy increases wit increase in forming angle. [4]In the present work effect of four forming parameters namely Step size, Wall angle, Feed rate and spindle speed is tested on surface roughness of Aluminium AA1100 sheets in ISF process.

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III. MATERIAL AND METHOD

A. *Material*

The aluminium material is finding wider applications in automotive industries due to its lightweight characteristics and as it is a non-corrosive metal. The forming force required for aluminium is less as compared to the steel. Thus, ISF finds greater application with aluminium material. The material used for the experimentation is Aluminium sheet AA1100 grade. This alloy is commercially pure aluminium with excellent forming characteristics. It is ideally suitable for cold working. It is commonly used in heat exchanger fins, sheet metal works, decorative parts, hollowware, name plates, architectural flashing lightly stressed panels, chemical handling equipment etc. This is a commercial alloy that contains minimum 99% of Aluminium, maximum 0.1% ofZinc, 0.05-0.2% of Copper, 0.05% of Manganese Silicon. The physical properties are listed in table 1.

Table 1: Physical properties of material [5]

Parameter	**Value**
Material	Aluminium AA1100
Density	2710 Kg/m3
Poisons ratio	0.33
Young Modulus	70 GPa
Tensile Strength	110 MPa
Yield Strength	105MPa
% Elongation	12%
Fatigue strength	41MPa

B. *Experimental Setup*

The experiments are performed on CNC SURYA VF 30 machine. It is having three axes with 800, 350 & 380 mm of transverse movement capacity in X, Y & Z axes respectively. This machine can carry maximum load of 300 Kg, has positional accuracy of ± 0.010 mm and repeatability of ± 0.005 mm. A hemispherical tool with 10 mm diameter is chosen for the forming purpose. This kind of tool is easy to manufacture and the cost is also low. A fixture was designed and manufacture to clamp the sheet. The machine, fixture and the tool are shown in figure1.

Fig. 1: Experimental setup

As literature reveals that the formability is higher at smooth radius than the sharp corners cone will have higher formability than other geometries thus cone geometry is preferred during this work. The geometry chosen for forming during this study is a truncated cone with base diameter 100 mm. The depth of the cone is arbitrarily chosen as 50 mm. The programming tool path used is of spiral shape. Siemens NX software package was used to generate the CNC codes.

C. *Design of Experiments*

The L9 orthogonal array is used to design the experiments in this study so that total number of experiments needs to be performed will be reduced. The L9 orthogonal is chosen as in this study effect of four parameters with three level each need to be studied. The parameters chosen for the study are step size, wall angle, feed rate and rotational spindle speed. Effect of these parameters is to be studied on surface finish of the formed part. Levels of the control factor are decided on the basis of literature review, CNC machine tool specifications and expert advice. The input parameters with their chosen levels are shown in table 2.

Table 2: Input parameter levels Control Factors

Control Factors	**Notation**	**Levels**			**Unit**
		1	**2**	**3**	
Step Size	S	0.1	1.0	2.0	mm
Wall Angle	W	65	55	45	degrees
Feed Rate	F	500	1500	2500	mm/min
Rotational Speed	R	100	1000	2000	RPM

IV. RESULT AND DISCUSSION

In this section the results of experimentation carried out are discussed in detail. Aluminium being a difficult method to form, the sheets were cracked before reaching the desired depth. In the beginning of the forming process the distribution of tensile stresses is homogeneous all over the

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workpiece. However, after deformation large amount of strains might gather in small area thus reducing cross sectional area. This thinning phenomenon is called as Necking. The reason for necking is due to the fact that all real materials are imperfect, in the sense that they have small local variations in dimensions and composition, which lead to local fluctuations in stresses and strains. The type of crack generated is a measure of process characterization.

Table 3: Sheet Depth

Experiment	Depth (mm)
I	6.861
II	8.051
III	7.520
IV	7.853
V	7.739
VI	12.139
VII	4.012
VIII	10.994
IX	10.399

The sheet depths were measured using video measuring machine. The depth achieved before crack is initiated is listed in Table II. It is seen that sheets with same geometry cracked at different depths and with different modes of cracking, indicating ISF being very sensitive process.

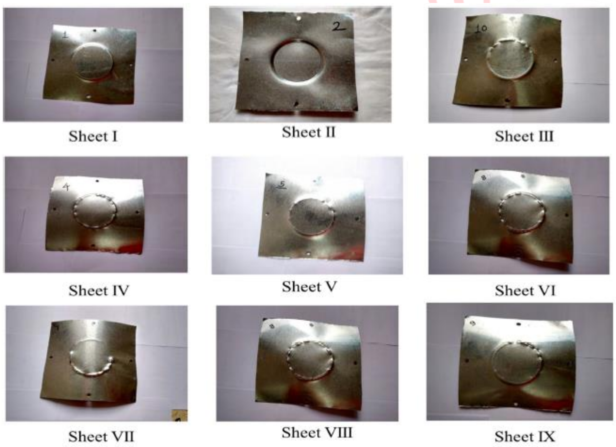

Fig. 3: Cracks generated in the sheets

Refer fig. 3 Sheet 1, a short transverse crack is visible in sheet I, which is circumferentially straight. A similar crack is observed in case of sheet II also. However, the crack in sheet II is initiated later than that of sheet I. In case of sheet III, the bottom is nearly torn off from all the sides with no wall forming. This kind of failure occurs when the forming tool is acting as a cutter. In general, stamping the remedy is to reduce the blank holder force or to increase the die entry radius. In incremental sheet forming, the bolt holding tension can be considered as equivalent to blank holding force (BHF). Thus, we can conclude that, the holding tension value is inappropriate for given process parameters.

In sheet IV, the crack is propagated in circumferential zig-zag manner. This may be explained as presence of foreign bodies in the sheet which causes thicker nodules to get pressed while forming thus disturbance is caused to flow stress resulting in this type of crack propagation. In sheet V, only a short wall stub is formed of the height of die edge curvature, the bottom started to tear off. Sheet VI is formed to considerable depth and then a crack is initiated at bottom flat of the sheet. There are two probable reasons for this. The first one is related to non-forming parameter of CNC program, the rate of tool penetration, if the rate is too high it will result in this type of crack. The reason which won't be applicable in this case is worn out die radius. Too high rate of penetration, i.e. tool lowering down at higher speed will cause localized deformation resulting in crack initiation.

Sheet VII is cracked prior to forming, this is due to non-suitable tool radius in context of the forming parameters. In case of sheet VIII, the crack observed in circumferential zig-zag in nature along with frayed wall edge and flattened wrinkles. The reason should be high value of through thickness shear stress resulting in such failure type. In sheet IX, the crack is initiated at bottom corner. Some bulging of bottom flat cab also be identified. This might be result of a localized pinch of sheet with tool. The effect of individual factor was analysed using ANOVA. The fig. 3 shows the factor effect plot for sheet depth. It can be seen that the wall angle is the most prominent factor affecting the depth value, followed by feed rate. These two factors put together influence 88% of results. The other two factors viz. step size and rotational speed are not so dominant with their percentage contribution of 8% and 5% respectively.

As evident from the graph, wall angle is the most dominant factor affecting the depth, with increase in wall angle, the depth decreases. Decreasing feed helps achieving the larger depth. With increase in feed rate the depth tends to decrease, i.e. formability decreases. The effect of step size is not being linear, higher depth can be achieved with step value, 1.0 mm but a decrease is observed at end values which are and 2.0 and 0.1 mm. Similar is the case with rotational spindle speed, except middle value being inferior than end levels. Thus, we can say that effect of step size and rotational spindle speed may not be clear from the performed experiments.

V. CONCLUSIONS

Following major conclusions can be drawn from current research work

1) The formability is mainly affected by the wall angle i.e. part geometry. Thus, designer should take proper care while designing a part for ISF process. Steep angles should be avoided as much as possible.

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2) Lower feed rates are advisable for higher formability. This is due to a material property strain rate sensitivity. Which states that the stress strain curve of a material is not constant but changes with the rate of application of strain.

3) The different modes of cracking revealed that the formability in the process is limited by necking as well as through thickness shear in the component which is due to serrated strain path resulting from cyclic plastic deformation.

4) Too high or too low values of step size are not advisable from formability point of view.

5) For the selected range of spindle speed, formability first decreases with increase in spindle speed and after certain value it again starts increasing.

REFERENCES

[1] Y. H. Kim, J. J. Park, "Effect of process parameters on formability in incremental forming of sheet metal", Journal of Materials Processing Technology, vol. 130-131, 2002, p. 42.

[2] Geeta B. Awankar, Mahendra G. Rathi, Amey S. Brahmagiri, "Study of Accuracy in Incremental Sheet Forming of Aluminium", International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol. 3, 2015, p. 439.

[3] Geeta B. Awankar, Mahendra G. Rathi, Amey S. Brahmagiri, "Experimental Investigation of Thickness Distribution in Incremental Sheet Forming for Aluminium", Journal of Material Science and Mechanical Engineering (JMSME), vol. 2, 2015, p. 31.

[4] G. Hussain, L. Gao, "A Novel Method to Test the Thinning Limits of Sheet Metals in Negative Incremental Forming," International Journal of Machine Tool & Manufacture, vol. 47, 200, p. 419.

[5] V. Mugendiran, A. Gnanavelbabu, "Comparison of FLD and Thickness Distribution on AA5052 Aluminium Alloy Formed Parts by Incremental Sheet Forming", in Proc. of 12th Global Congress on Manufacturing and Management, GCMM, Procedia Engineering, vol. 97, 2014, p. 1983.

[6] www.efunda.com/material/alloys/aluminium

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