Novateur Publication's
International Journal of Innovation in Engineering, Research and Technology [IJIERT]
ICITDCEME'15 Conference Proceedings
ISSN No - 2394-3696

PARAMETRIC INVESTIGATION OF SINGLE POINT INCREMENTAL FORMING OF COMMERCIAL ALUMINUM ALLOY

Anjali Shrikant Mulay
Department of Mechanical Engineering,
PDVVP College of Engineering, Ahmednagar, India

Ravi R. Navthar
Department of Mechanical Engineering,
PDVVP College of Engineering, Ahmednagar, India

ABSTRACT

Single point incremental forming (SPIF) is a new innovative and feasible solution for the rapid prototyping and the manufacturing of small batch sheet parts. In the present study experiments were conducted to analyze the effect of process parameters on the formability of commercial aluminum alloy AA1100. Major process parameters like Wall angle, Step increment, Feed rate, and Spindle speed, are set at three levels and experiments were designed by using the Taguchi method to get the two response parameters, wall thickness and surface finish. Analysis of variance shows that surface roughness depends on step increment by 64.19 % and wall angle by 17.23 %. For thickness reduction only wall angle (99.79 %) is responsible. For achieving better surface finish we need to control wall angle, step increment and feed rate while for thickness reduction we have to control only wall angle.

KEYWORDS: SPIF, Prototype, Forming limit curve, Formability, ANOVA.

INTRODUCTION-

For small scale production, the most economical sheet metal operation is single point incremental forming as it is a die-less process. The deformation of the material is carried out incrementally and as a consequence, less forming loads are required as compared to the conventional processes. In accordance to figure 1, the sheet undergoes progressive local plastic deformation, produced by the tool which has a hemi-spherical head. The process is carried out at room temperature and requires a CNC machining center, a hemispherical headed tool and a simple support to fix the sheet being formed. In incremental Sheet Metal Forming the blank is incrementally deformed in to a desirable shape by hemispherical or ball nose tool traveling along a programmed path. Due to the various advantages including the reduced production cost and time of prototypes, improved formability, easy modification of part design etc. the ISF is being popular as a new innovative forming technology. SPIF process performance is affected by various factors like tool path, sheet material, forming angle, tool size, step size, forming speeds (tool rotation and feed rate), lubrication and shape. The tool path is generated according to the profile of the CAD models. This package is usually used for material removal in milling and is perfect for SPIF because its built-in path generation algorithm can be used to guide the forming tool. The angle that the side walls of a part make with the horizontal xy-plane is known as forming angle. The extent of this angle depends mainly on material properties and the sheet thickness. Nonetheless, SPIF parts are controlled by the maximum forming angle (Ø max) to which a material can be drawn before catastrophic failure in a single forming pass. Tool size greatly affects both the formability and the surface finish of the manufactured part through this process. Experiments have shown that smaller radius tools have higher formability than larger ones. The influence of step size on the formability along with how much it influences the SPIF process is still a debatable parameter.

ISSN No - 2394-3696

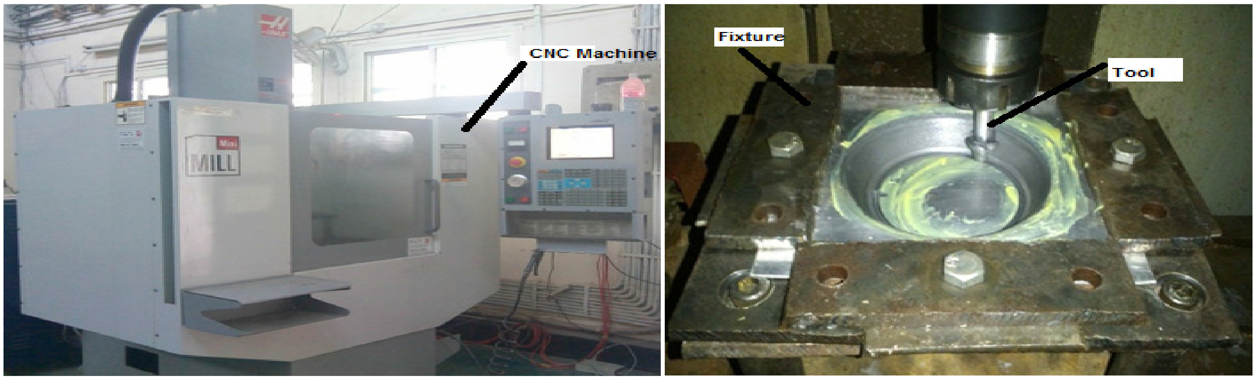

Figure 1: Single point incremental forming set up

Some researchers hold that step size does not influence formability but rather it only affects surface roughness. While others believe that it does influences formability and by increasing the step size there is a decrease in the formability. The influence of forming speed, both rotational spindle speed and feed rate are important regarding the SPIF process. The relative motion between the tool and sheet is directly proportional to the heat that is generated by friction. Formability differs between materials. Previous literature study reveals that the strain hardening coefficient (n) as well as the interaction between the strength and strain hardening coefficient have the highest influence on formability. Lubrication is major influential parameter is SPIF in order to reduce to reduce tool wear and improve surface quality.

PROBLEM DEFINITION

The currently used methods of sheet metal forming are suitable for forming of soft materials. However, one important drawback is that the forces on the forming become high when forming thicker material. Therefore, it is generally not possible to substantially form harder and stronger but less ductile materials, such as high strength alloys. Another drawback is the difficulty to create clearly localized slope changes within complex products in order to meet the requirements. Selection of process parameters (wall angle, tool rotation, vertical step size, tool diameter and lubrication) is difficult to control thickness reduction and avoid surface wear and ductile damage in incremental sheet metal forming.
In the present research work, attempt has been made to analyze the impact of major process parameters and their mutual interaction on the ductile damage as well as identification of optimum parameter to achieve greater surface finish and to control wall thickness.

EXPERIMENTAL WORK

All the experiments were performed on 3 axis CNC HAAS Mini Milling machine in Production department, Indo German Tool Room, Aurangabad, India shown in figure 1. In CNC HAAS the tool is controlled by a computer and is programmed with a machine code system that enables it to be operated with minimal supervision and with a great deal of repeatability. The characterization of this tool path is only a continuous feed rate in X and Y direction of a deformed sheet plane. The feed rate in the Z direction is done in the angular position. Z axis of travel machine is the up-and-down. CNC machine uses computer program written in the notation called G code. Program can be transferred by using computer system connected with machine or by using floppy drive. CAD geometries were generated with UGNX 8.5 and CAM tool paths were designed with UGNX 8.5 CAM. Mill contour machining environment were used to generate contour tool path. Program and tool path were generated for cavity mill, which is cutting operation. Mill finish method was selected and profile cut pattern were used to follow only periphery. FANUC postprocessor used to generate the program that contains G & M code. Lubricant was used in form of a thin film over the sheet being formed in form of a lubricant pool to avoid this and to reduce the impact of friction between the forming tool and the sheet. Clamping system is designed according to guidelines provided in NUMISHEET 2014- benchmark problem 3. The whole apparatus is clamped to the bottom corners of the working table of the CNC by two T bolt and nut.

ISSN No - 2394-3696

Apart from iron, aluminum is currently the next most widely used metal in the world. This is due to the fact that aluminum has a unique combination of attractive properties. Properties such as its low weight, corrosion resistance, and easy maintenance of final product, have ensured that this metal and its alloys will be in use for a very long time. The chemical composition and mechanical properties are shown in table 1 and table 2 respectively. Castrol Illoform TDN 81 was used under the different process conditions on the AA8011 material. The chemical composition and mechanical properties are shown in table 1 and table 2 respectively. Experiments were performed to analyze effect of wall angle, step size, and tool diameter, spindle speed and feed rate on formability of commercial aluminum alloy. At initial stage experiments were carried out by using material AA8011. Constant angle test were designed to evaluate the formability of material at an angle 55^0, 65^0 and 75^0. During these experiments, spindle speeds of 1000 rpm and feed rate of 1500 mm/min were held constant throughout the experiments. All the parts were formed in a cone shape with a diameter of 94 mm and to achieve depth of 50 mm. Following table 3 shows the variable parameter combination during the experiments. For AA8011 experiments were formed according to L_9 orthogonal array to obtain the quantitative values of response parameters.

Table 1. Chemical composition of AA 8100

Element	Contribution (%)
Al	97.3-98.9
Fe	0.6-1
Mn	0.2
Zn	0.1
Cu	0.1
Ti	0.08
Cr	0.05
Mg	0.05
Reminder	0.15

Table 2. Mechanical properties of AA 8100

Parameter	Value
Density	2.71 g/cm^3
Young's modulus	72 GPa
Poisson's ratio	0.27
Ultimate tensile strength	150 MPa
Maximum elongation strength	50-60 %

DESIGN OF EXPERIMENTS- TAGUCHI METHOD

The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Englishman, Sir R.A.Fisher.

The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments which produces the most information is known as a partial fraction experiment. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments. Taguchi constructed a special set of general design guidelines for factorial experiments that cover many applications.

Taguchi has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulate the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment. The L9 orthogonal array is meant for understanding the effect of 4 independent factors each having three factor level values as shown in the table 4.

Table 3. Single point incremental forming parameter and their levels

.

Factors	**Unit**	**Level 1**	**Level 2**	**Level 3**
Wall angle	degrees	55	65	45
Step increment	mm	0.2	0.5	1
Feed rate	mm/min	500	800	1200
Spindle speed	rpm	600	800	1000

Table 4. Plan of Experiments using L9 Orthogonal Array

Experiment No.	**Wall angle**	**Step increment**	**Feed rate**	**Spindle speed**
1	55	0.2	500	600
2	55	0.5	800	800
3	55	1	1200	1000
4	65	0.2	800	1000
5	65	0.5	1200	600
6	65	1	500	800
7	45	0.2	1200	800
8	45	0.5	500	1000
9	45	1	800	600

RESULT AND DISCUSSION

Thickness is measured from top to bottom at the depth of 15 mm, 30 mm, 45 mm, 60 mm and 70 mm. Surface qualities is measured at five different points and average response of wall thickness (mm) and surface roughness. In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value for the output characteristic. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available depending on type of characteristic: Target is best, Smaller is better, and Larger is better.

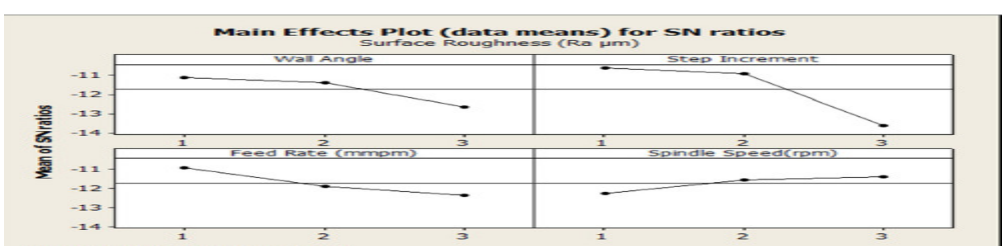

Figure 2: S/N Ratio Graph for surface Roughness

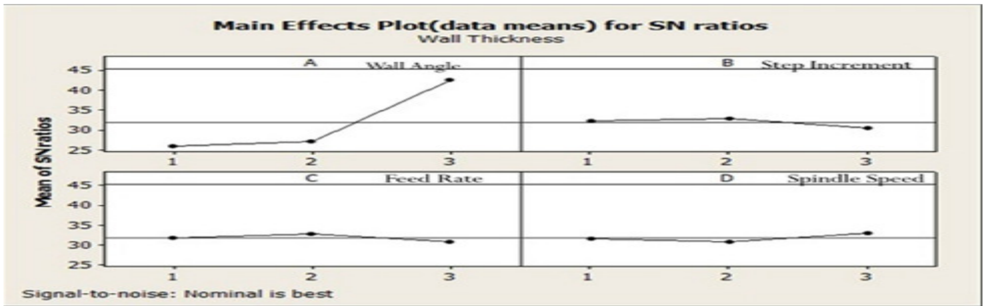

Figure 3: S/N Ratio Graph for Wall Thickness

From the S/N ratio analysis in figure 2 and figure 3 reveal that, optimal conditions for Surface finish are wall angle 55^0 (level 1), Step Increment 0.2 mm (level 1), Feed rate 500 mm/min (level 1) and Spindle Speed 1200 rpm (level3). S/N ratio analysis of figure 4.12 shows only wall angle affect significantly on sheet thickness reduction because there is no large deviation of S/N ratios of Step increment, Feed rate and Spindle speed from mean value. ANOVA was used to determine the significant parameters influencing surface finish and wall thickness in the forming of AA8011. Table 4 shows summery of ANOVA results for surface roughness and wall angle. In this study, analysis was a level of significance as 5% and level of confidence as 95%.

Table 4. ANOVA result for surface roughness and wall thickness

		ANOVA for Surface Roughness			**ANOVA for Wall thickness**		
Factors	**DOE**	**Sum of Squares**	**Mean of squares**	**Contribution**	**Sum of Squares**	**Mean of squares**	**Contribution**
Wall angle	2	1.0114	0.5057	17.23	0.38315	0.19158	99.79
Step increment	2	3.7685	1.8843	64.19	0.0002	0.0001	0.05
Feed rate	2	0.6664	0.3332	11.35	0.0003	0.0002	0.08
Spindle speed	2	0.4244	0.2122	7.23	0.0003	0.0001	0.07
Error	0	0			0	0	
Total	8	5.8707			0.3839		

From the above ANOVA results it is clear that surface roughness is depends on step increment by 64.19 % and wall angle by 17.23 %. For thickness reduction only wall angle (99.79 %) is responsible. For achieving better surface finish we need to control three parameters but for thickness reduction we have to control only one parameter i. e. wall angle. Parameter which defines the contact between sheet and tool are important for surface finish, means surface finish is depends on contact area and contact time between tool and sheet. More thickness reduction can be achieved for greater wall angle, this is only due to the less sheet material is available for deformation at large wall angle.

CONCLUSIONS

The following conclusions can be made out of this investigation,

1. With smaller vertical step forming forces decreases and larger depth can be achieved with better surface finish. From the ANOVA results it is clear that surface roughness is depends on step increment by 64.19 % and wall angle by 17.23 %.
2. Thickness reduction is depends on only wall angle, its dependency is 99.79 %

3. Feed rate and spindle speed does not have significant effect on surface finish and thickness reduction.
4. Tool size affects both the formability and the surface finish of the manufactured part.
5. Biaxial stretching at the corners and plain strain stretching at the sides produced. This is the reason crack occurred mostly at the corner.

REFERENCES

[1] I. Cerro, E. Maidagan, J. Arana, a. Rivero & P.P. Rodríguez.(2006) Theoretical and experimental analysis of the dieless incremental sheet forming process. J. Mater. Process. Technol. 177, 404–408.
[2] J. Duflou, Y. Tunçkol, A. Szekeres & P. Vanherck (2007) Experimental study on force measurements for single point incremental forming, J. Mater. Process. Technol. 189 , 65–72.
[3] G. Hussain, L. Gao, N. Hayat & L. Qijian. (2007) The effect of variation in the curvature of part on the formability in incremental forming: An experimental investigation, Int. J. Mach. Tools Manuf. 47, 2177–2181.
[4] G. Hussain, N. Hayat & L. Gao. (2008) An experimental study on the effect of thinning band on the sheet formability in negative incremental forming, Int. J. Mach. Tools Manuf. 48, 1170–1178.
[5] J. Li, C. Li & T. Zhou. (2012) Thickness distribution and mechanical property of sheet metal incremental forming based on numerical simulation, Trans. Nonferrous Met. Soc. China,22, s54–s60.
[6] M. Durante, a. Formisano, a. Langella & F.M. Capece Minutolo. (2009) The influence of tool rotation on an incremental forming process, J. Mater. Process. Technol, 209, 4621–4626.
[7] G.L. Manco & G. Ambrogio. (2010) Influence of thickness on formability in 6082-T6, Int. J. Mater. Form., 3, 983–986.
[8] S. Dejardin, S. Thibaud, J.C. Gelin & G. Michel. (2010) Experimental investigations and numerical analysis for improving knowledge of incremental sheet forming process for sheet metal parts, J. Mater. Process. Technol., 210, 363–369.
[9] G. Hussain, G. Lin & N. Hayat. (2011) Improving profile accuracy in SPIF process through statistical optimization of forming parameters, J. Mech. Sci. Technol., 25, 177–182.
[10] S.P. Shanmuganatan & V.S. Senthil Kumar. (2012) Experimental investigation and finite element modeling on profile forming of conical component using Al 3003(O) alloy, Mater. Des., 36, 564–569.