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OPTIMIZATION OF PROCESS PARAMETERS FOR INCREMENTAL SHEET FORMING PROCESS

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Abstract: Conventional forming process, without die and punch press, cannot be completed for desired product output and it leads to higher cost of setup forming process in industries, especially in automotive and sheet metal industries. To come over this cost factor, there is need of unique process for forming of sheet metal which eliminates higher setup cost of die and punch press. Considering lead time for process starting, it also takes higher lead time in conventional process which also effects on ultimate manufacturing cost. To optimise both the factors Incremental Sheet Forming (ISF) represents the easiest and the cheapest process among all the innovative sheet metal forming processes. Flexibility and set-up cost reduction are main base of this process which provides multitasking to user for any shape of product manufacturing. Process can be experimented using simple blank holding component and universal round-ball ended tool. Pre-generated tool path, developed in CAD/CAM system, need to be integrated in CNC vertical milling centre. To conclude the optimum process parameters in ISF, Taguchi method of DOE with ANOVA and L9 orthogonal array was developed for different process parameter factors such as feed rate, speed of spindle, wall angle, and step-depth increment. Study of output was performed on wall thickness and surface roughness of process.
KeyWords: ISF, Die-less process, Forming, ANOVA etc.

I. INTRODUCTION

Incremental forming is the process of forming sheet material into complicated shapes without the use of dies. Single point incremental forming (SPIF)is a new innovative and feasible solution for the rapid prototyping and the manufacturing of small batch sheet parts. The process is carried out at room temperature and requires a CNC machining centre, a spherical headed tool and a simple support to fix the sheet being formed. In incremental Sheet Metal Forming the blank is incrementally deformed into a desirable shape by hemispherical or ball nose tool traveling along a prescribed path. Due to various advantages such as low cost, short lead time, good flexibility due to absence of dies and good surface finish can be achieved. With ISF approach, the deformation of the material is carried out incrementally and as a consequence, less forming loads are required comparing with the conventional processes. Single point incremental sheet forming has four basic elements:

1) A sheet metal blank
2) A blank holder
3) A single point forming tool
4) Backing plate & CNC motion.

These basic elements are illustrated in Figure 1.F is the metal forming force, v is the tool feed and ω is the spindle rpm. The ISF technology is a forming approach which uses the CNC machining centre, a spherical headed tool and a simple support to fix to produce a part from the sheet materials. The flexibility of the process is mainly related to the fact that SPIF does not require a dedicated die to operate as compared to other forming processes .ISF is a highly localized deformation process in which a tool, whose path is programmed to follow a particular trajectory, moves over a sheet metal and forms the desired shape. Three dimensional models of the part are designed using commercially available CAD/CAM software Feature CAM and CNC codes are generated by the same software. The codes are then fed into the CNC machine. As a result, the lead-time and cost of tooling along with the die cost can be avoided. This technique allows a relatively fast and cheap production of small series of sheet metal parts. Figure 2 gives the schematic representation of elements of ISF.

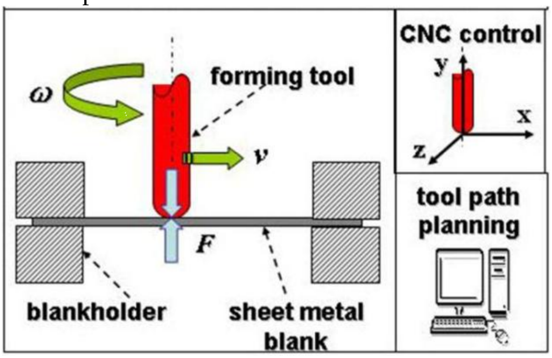

Figure1. –Basic Elements of SPIF

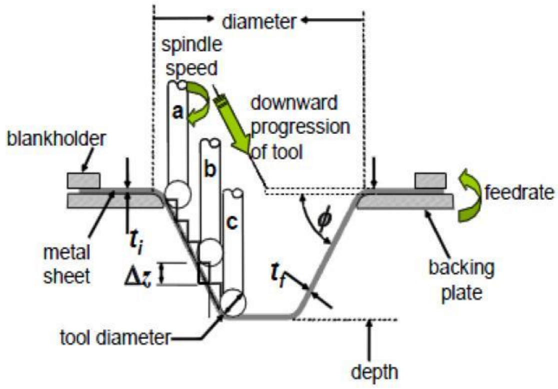

Fig.2 ISF Process Terminology

II. EXPERIMENTAL METHODOLOGY

2.1 CAD/CAM design development

Pyramidal shape as shown in figure 3 was designed drawn in one operation in order to investigate incremental sheet metal forming process. Geometries were generated with CAD software and tool paths are designed with CAE/CAM as shown in figure 4.

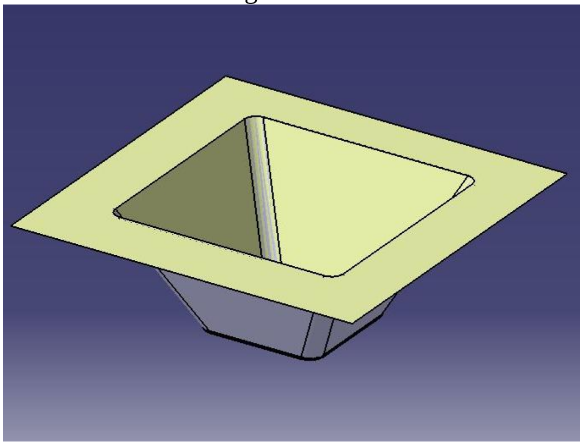

Figure 3 Pyramidal geometries

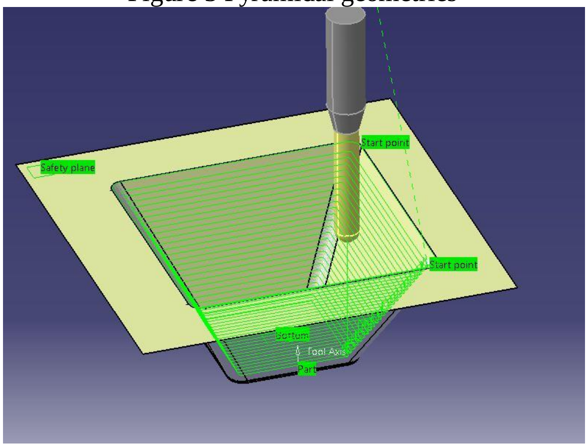

Figure 4 Tool path

2.2 Blank Holding components and tool

Design of fixture:Fixture need to be designed to hold blank against overhead tool force, so sheet metal deformation can take place on sheet. Fixture is a device fixed to the worktable of a machine and locates the work in an exact position relative to the cutting tool. It is mainly used for locate, holding and clamping purpose. The majority of fixtures in use today are termed as dedicated work holding devices since their configuration is fixed for one work piece geometry. Maximum productivity at minimum cost is the demand of modern industry. To meet this requirement designing of efficient and accurate fixture is required. Quality, simplicity and economy from the important criteria for the design of fixtures .To meet this requirement the designer will have to make an economic analysis for using jigs and fixtures and has to device certain principles of design.Figure 5 shows CAD assembly of base plate and top plate with blank in between and figure 6 shows developed fixture.

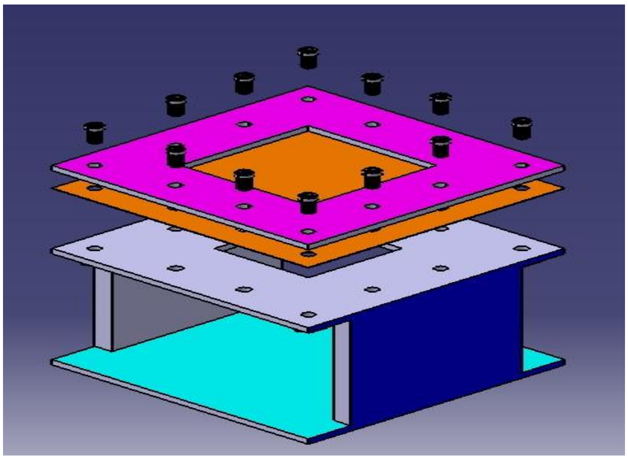

Figure 5 Design of fixture

Figure 6 Development of Fixture

Design of tool: No specially designed tool is needed in ISF, as simple round ball ended tool can be used universally with desired diameter depending upon workpiece material. Figure 7 shows three different tools of different diameters of 8mm, 10mm and 12mm. CNC tool post can hold it easily and forming can be inscribed in sheet for pre-generated tool path of desired final product. Materials can be SS304 for tool with fine polished ball end to reduce deformation and roughness values. Figure 8 shows developed tools.

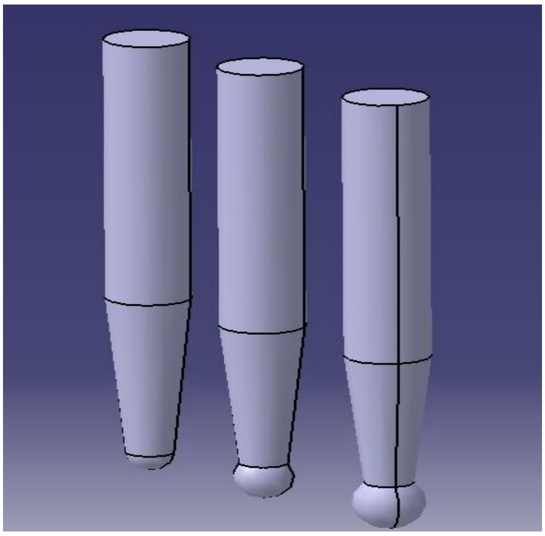

Figure 7 Design of tool

Figure 8 Development of Tool

2.3 Taguchi method

Design of experiment: Taguchi method is adopted for optimizing process variables as it is simple and easy. The method is popularly known as the factorial design of experiments. This methoduses a special set of arrays called orthogonal arrays. 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 3 factor level values.

Table 1-SPIF Parameter and their levels

Factor	Unit	Level1	Level2	Level3
Wall angle	Degree	45	55	65
Step increment	mm	0.2	0.5	1
Feed rate	mm/min	500	800	1200
Spindle speed	rpm/min	600	800	1000

Table 2 - Orthogonal Array L9

Exp no.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

III. RESULTS AND ANALYSIS

3.1 Results of DOE - Taguchi Method

Table 3–Experimental Results of Taguchi Method

	Factor				**Response**	
Ext no	Wall Angle	Step Depth	Feed Rate	Spindle Speed	Surface Roughness	Wall thickness
1	45	0.2	500	800	4.87	1.26
2	45	0.5	800	1000	4.36	1.27
3	45	1	1200	600	6.69	1.26
4	55	0.2	800	1000	4.11	0.73
5	55	0.5	1200	600	4.76	0.77
6	55	1	500	800	5.02	0.75
7	65	0.2	1200	600	4.02	0.98
8	65	0.5	500	800	4.18	0.97
9	65	1	800	1000	5.54	0.99

3.2 Analysis of Variance (ANOVA)

ANOVA was used to determine the significant parameters influencing surface finish and wall thickness in the forming of AA1100. Table 3 and 4 shows summery of ANOVA results for surface roughness and wall angle. In this study analysis was level of significance as 5% and level of confidence as 95%

Table 4–ANOVA Results for Surface roughness

Factor	DOF	Sumof Square	Mean Square	Contribution %
WallAngle	2	1.0231	0.5057	18.76
StepDepth	2	3.7546	1.8843	63.56
FeedRate	2	0.6764	0.3332	11.35
SpindleSpeed	2	0.4176	0.2122	6.33
Error	0	0		
Total	8	5.8717		100

Table 5–ANOVA Results for Wall thickness

Factor	DOF	Sumof Square	Mean Square	Contribution %
WallAngle	2	0.38315	0.19158	99.68
StepDepth	2	0.0002	0.0001	0.09
FeedRate	2	0.0003	0.0002	0.12
SpindleSpeed	2	0.0003	0.000	0.11
Error	0	0	0	
Total	8	0.38395		100

From the above ANOVA results it is clear that surface roughness is depends on step increment (Depth) by 63.56% and wall angle by 18.76 %. For thickness reduction only wall angle (99.68 %) 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. Design of experiments by using Taguchi Method gives the two responses, surface finish and wall thickness and ANOVA gives most influencing parameter on the response. The results shows optimal conditions wall angle, step increment, feed rate and spindle speed are important for better Surface finish but for sheet thickness reduction only optimal wall angle must be set, because there is no large deviation due to Step increment, Feed rate and spindle speed from mean value for thickness reduction. ANOVA results shows step increment is important parameter for surface finish as its effect on surface roughness is 63.56% and wall angle is most influencing parameter for wallthickness distribution as its effect on it is 99.68%. For obtaining better surface finish we need to adjust two parameters, step increment and feed rate. 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.

IV. CONCLUSIONS

Truncated pyramid profile was developed successfully. The deformation values obtained was according to the tool path defined. The values of variation in thickness matched closely with the theoretical values related to FLD curve validating the correctness of process. From ANOVA results it is concluded that

a) Surface roughness depends on step increment (Depth) by 63.56% and wall angle by 18.76%.

b) Thickness reduction is depends on only wall angle, its dependency is 99.68%

c) Feed rate and spindle speed does not have significant effect on surface finish

d) Feed rate and spindle speed does not have significant effect on thickness reduction

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