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APPLYING A NEW METHOD FOR INCREMENTAL SHEET METAL FORMING WITH HIGH SPEED

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ABSTRACT

Recently, incremental sheet metal forming (ISMF) process as one of the new methods in rapid prototyping (RP) collection has been attended by researchers. This process based on defined path in CNC machine controller and applying a head-spherical tool, supplies the required force for sheet metal forming. Despite affirmation of process ability in forming of symmetric geometries, some of their aspects such as: high cost in die design and its manufacturing (specially in two point incremental forming process), high cost in using of CNC machine tools and long time for forming, are as process constraints. Hereupon and acquitting of above constraints, the new method for incremental sheet metal forming on turning machine has been presented. This process without needing to die and using a head-spherical tool stated in tool-holder turret forms the sheet metal in symmetric geometries and in possible shortest time. In continues, with a view to increasing of sheet formability in this process, two types of forming strategies were designed and executed. In final, the best forming strategy based on final forming depth and effective strain calculations was introduced.

KEYWORDS: Rapid prototyping, Incremental sheet metal forming, Sheet formability.

1. INTRODUCTION

Incremental forming process is a technology for sheet metal forming that has been controlled numerically and investigated in recent years [1, 2]. This method is economic process for low production volume and special for single production. Ability of this process for different applications such as: manufacturing of automotive pieces [3], medic productions [4] and aviation industrial pieces has been confirmed. Speed of forming in this process is slow in comparison with other forming processes. Because imposing deformation by tool is local and hence increases sheet formability [5, 6]. So, for increasing of forming speed, high speed incremental forming process (HSIF) can be investigated. With the view of, in present research incremental sheet metal forming process on turning machine has been investigated. This new process respect to time and cost has considerable efficiency. The presented method, using a head-spherical tool without die, forms the clamped sheet on fixture in symmetric geometry that describe as follows.

2. COMPARISON BETWEEN SPINNING PROCESS AND NEW METHOD

Spinning is a cold-forming operation where a rotating disk of sheet metal is progressively shaped over a mandrel to produce rotationally symmetrical shapes. Localized pressure is applied through small roller, which traverses the entire surface of the part to produce the progressive deformation. Although the spinning process is a traditional manufacturing technique, it is still a popular and common topic to study. There are many differences between spinning process and new defined method basically. Some of these differences have been shown in Table.1.

Table.1: Comparison between spinning process and new method

Title	Spinning	New method
Tool geometry	*Disk tool*	*Spherical or hemispherical tool*
Die geometry	*Manufactured according to final desired shape*	*No need to a die*
Condition of sheet clamping	*Situated in the outside floor of sheet*	*Situated in the perimeter of sheet*
Distribution of sheet thickness after process execution	In floor of sheet: *approximately constant* In wall of sheet: *Variety of thickness*	In floor and wall of sheet: *Approximately same in all points*
Speed of process	*Very high*	*Incremental, high*
Shape of final product	*According to applied die*	*Symmetric shapes: Cylindrical, conic …*

3. PRINCIPALS OF PROCESS EXECUTION

In this new method, the sheet metal by applying a turning machine, a fixture, a tool and adequate lubricant will be formed incrementally. This process uses any pre-manufactured pattern or dies under the sheet. Task of fixture is avouching and conducting the sheet metal at forming area, as sheet boundary was clamped altogether on the fixture. Tool on the turret of turning machine and fixture with together clamped sheet, will be attached on chuck tightly. Fixture together with sheet has rotational motion and forming tool has both vertical and radial motion. At the beginning of process, the forming tool moves inside sheet vertically equal to vertical step size and then travels linearly along radial. The produced sample has symmetric geometry with closed end.

3.1. Test for possibility of process execution

With a view of accrediting successful execution, forming process was tested on the annealed aluminium sheet. So, fixture that consists of main base and ring piece (Fig.1) and tool forming that consists of main base and ball (Fig.2) was manufactured according to designed sketch. The ring piece applies the equal pressure on the sheet for safe clamping and will prevent from sheet motion. On the other hand, the ball in end of tool has free rotational movement.

Fig.1. Fixture

Fig.2. Forming tool

Then, sheet with 1(mm) thickness was cut to determined dimensions (150 x 150 mm) and for clamping on top of the fixture was drilled on the allocated positions (Fig.3). Next, fixture together with clamped sheet lied on the chuck of turning machine (Fig.4).

Fig.3. Clamping of annealed Al sheet on the fixture

Fig.4. Attaching the fixture on the chuck

Also, after concentric adjustment between ball and sheet center, forming tool was avouched on the tool-holder turret. For sheet deformation and checking of sheet behaviour in this process, different values of parameters were used. These parameters are: vertical feeding step size of tool at sheet inside (v_f), rotational speed of chuck (s), automatic radial feeding of tool (f) and diameter of forming zone (d_f). When first tearing was appeared in end of sheet, the process will be stopped (Fig.5).

Fig.5. Process execution

At the end of process, sheet was formed in cone geometry (Fig.6). Then, the initial of formed sample was produced successfully and ability of this new method for forming of symmetric geometries was approved. So, presented method will open a new path for researchers and industrialists. In the next section, two strategies for forming process will be studied.

Fig.6. The formed sheet in cone geometry

4. EFFECT OF FORMING STRATEGY ON SHEET FORMABILITY

Forming strategy is one of the effective parameters in incremental forming process. In this process, the strain-hardening effects will be appeared. When imposing deformation on the sheet was increased, this affect will be enlarged. This means that whenever the process has been carried out, sheet behavior differ in any level of forming process and deformation will be created in weakest zone of sheet metal undesirably. This effect can be controlled by forming strategy variation and decreasing of deformation in any level of forming process.
To study the forming strategy in defined process and its effect circumstance on the final sheet deformation, two experimental tests base on two different strategies were designed:

1. In first test, after applying of vertical feeding step size at sheet center by forming tool (v_{f1}), the forming tool will moves toward sheet boundary. Automatic radial feeding of tool in this motion is f, then forming tool without any imposing secondary load in sheet boundary, will travel toward sheet center. The above cycle will continue until the initial tearing was appeared on the sheet (Fig.7).

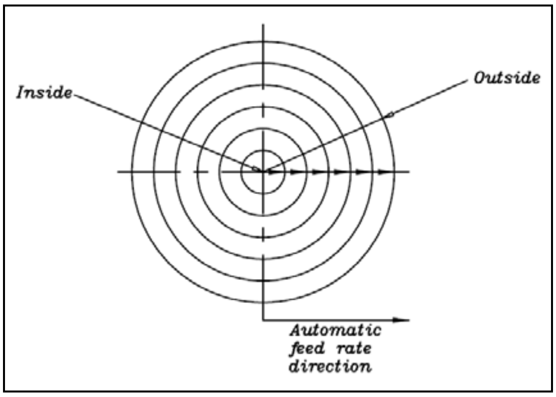

Fig.7. Schematic of the first strategy forming

2. In second test, after applying of vertical feeding step size at sheet boundary by forming tool (v_{f1}), the forming tool will move toward sheet center. Automatic radial feeding of tool in this motion is f, then forming tool without any imposing secondary load in sheet center, will travel toward sheet boundary. The above cycle will continue until the initial tearing was appeared on the sheet (Fig.8).

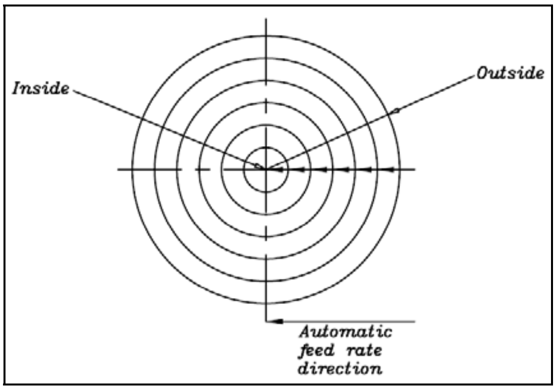

Fig.8. Schematic of the second strategy forming

4.1. Test execution

Adjusted parameters for implementation of tests are:

. Vertical feeding step size of tool: $v_f = 0.5\ mm$

. Rotational speed of chuck: $s = 26\ rpm$

. Automatic radial feeding of tool: $f = 1.984\ mm/rev$

. Diameter of forming zone: $d_f = 60\ mm$

In continues, two annealed Al sheets were accommodated in 150X150 mm dimensions with $1\ mm$ thicknesses. Study criterion of sheet formability in this process is final forming depth and effective strain ($\bar{\varepsilon}$). In order to determining of effective strain (based on von-mises yielding criterion), a circle by diameter: $d_0 = 25\ mm$ was drawn on the back and center of sheets by beam compass (Fig.9). According to designed process and adjusted parameters, the tests were executed. This forming process need to lubricate on the sheet surface. Lubrication will be decreased the friction between tool and sheet surfaces and will absorb heat of deformation.

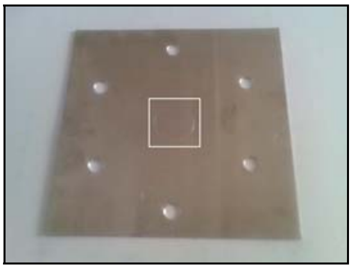

Fig.9. Drawing of circle on the back and center of the sheet

Amount of lubricant related to material type and thickness of sheet. In this process was used from HLP46 as lubricant. Apparition of initial crack or tearing in the formed sheets is sign for end of process. Fig.10 and Fig.11 show the formed sheets from first and second strategy forming respectively. Determined zones show the appeared crack in sheet boundary.

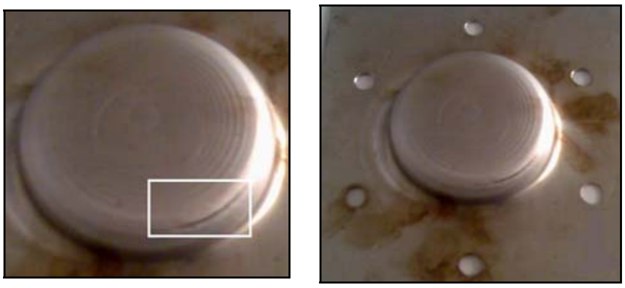

Fig.10. The formed sheet by first strategy

Fig.11. The formed sheet by second strategy

4.2. Derivation and analysis of results

In attention to vertical feeding step size of tool at sheet inside ($v_f = 0.5\ mm$), the samples were torn in below depths:

1. The sample based on the first strategy, in depth: $h_{total} = 18mm$ (step no. = 36)
2. The sample based on the second strategy, in depth: $h_{total} = 14.5mm$ (step no. = 29)

So, in the same condition of sheet material, sheet thickness, lubricant, parameters adjustment and process execution, maximum of forming depth was reached by using the first strategy. On the other hand, after checking of samples, the circles by diameter d_0 on the sheets were deformed to circles by different diameters d_1, d_2 (elliptical). Hence, by measuring of diameters d_1, d_2 with a caliper, three main strains $\varepsilon_1, \varepsilon_2, \varepsilon_3$ were calculated from below relations:

$$\varepsilon_1 = \ln(\frac{d_1}{d_0})$$

$$\varepsilon_2 = \ln(\frac{d_2}{d_0})$$

$$\varepsilon_3 = -(\varepsilon_1 + \varepsilon_2)$$

After calculation of main strains, the effective strain based on Von-Mises criterion will be calculated:

$$\bar{\varepsilon} = \left[\frac{2}{3}(\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2)\right]^{\frac{1}{2}}$$

Table.2 shows the results of diameters d_1, d_2 measuring and values of main and effective strains.

Test no.	1	2
$d_1(mm)$	28.3	26.12
$d_2(mm)$	28.16	26.05
ε_1	0.124	0.0438
ε_2	0.119	0.0411
ε_3	-0.243	-0.0849
$\bar{\varepsilon}$	0.243	0.0849

Based on the above results and ratio value of effective strain in the first test to the second test ($\bar{\varepsilon}_1/\bar{\varepsilon}_2 = 0.243/0.0849 = 2.86$), predominance of the first strategy in this process has been confirmed again.

5. DISCUSSIONS

This phenomenon is justifiable as follow: since the boundary of the sheet metal by using a ring piece has been fixed and the center of sheet is free, the stiffness and rigidity of the boundary is large and the stiffness and rigidity of the center is small. So for achievement of high values of sheet formability and forming depth, every incremental step should be considered as a priority in the sequence from small stiffness to large one, which can make the center of a sheet with small stiffness, initially experience plastic deformation first, and make the boundary of a sheet with large stiffness experience a certain deformation and working hardness simultaneously. Thus, the plastic deformation of the center can be increased and the plastic deformation of the boundary can be decreased, which improves the degree of evenness of the deformation.

6. CONCLUSIONS

In this paper, the new method for incremental sheet metal forming on the turning machine was presented. This process is subset of high speed incremental forming (HSIF) processes. Forming principals of these processes is based on incremental forming but the time of forming is very short. In attention to executed experiments, ability of this process for forming of symmetric geometries was approved. Also, the best strategy for achievement of high values of sheet formability and forming depth was acquired. Finally, the first strategy (loading in center of sheet and then going toward boundary of sheet) was selected as the best strategy.

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