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FEA Analysis to Study the Influence of Various Forming Parameters on Springback Occurs In Single Point Incremental Forming

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ABSTRACT
The involvement of computer in manufacturing had result in the development of many modern manufacturing processes, among which one is the Incremental sheet metal forming (ISMF). ISMF is a modification of conventional sheet metal forming process, in which a hemispherical tool which is in the regular contact with the sheet metal moves under a control in three dimensional space and produces the plastic deformation of sheet layer by layer in incremental steps. Previous researches have shown that in ISMF, springback is major factor that affects the accuracy of the job. Controlling of springback is essential to improve the geometrical accuracy of the job. In the present work, the effect of various forming parameters like forming angle (α), tool diameter (*td*), step size (*dz*), sheet thickness (T_s) on the local springback in ISMF is studied..
Keywords – Geometric Accuracy, Increment Sheet Metal forming, Springback.

I. INTRODUCTION

Incremental sheet metal forming (ISMF) is a new innovative combination of computer technology with machine, and this makes it a flexible process. The complicated geometry information is resolved into a series of two-dimensional layers, and then the plastic deformation is carried out layer-by-layer through the CNC controlled movements of a simple hemispherical forming tool to get the desired part [1]. Springback is one of the sheet metal forming defects, which is the most difficult to control and results in geometrical inaccuracy. Many researchers committed to find an effective method to reduce the springback. Trial-and-error, as a traditional method, has been used to compensate the springback.

There have been many researches about springback prediction in ISMF processes. In [2], authors investigated investigated springback prediction in the ISMF process using a genetic neural network. However, the optimization speed was slow, and the accuracy was not very high. In [3], authors investigated material formability in incremental forming and, in particular, the evaluation and compensation of elastic springback through experimental investigation and explicit FEM analysis. In [4], authors investigated the negative springback phenomenon in sheet metal obtained by the incremental forward stretch forming operation, both experimentally and numerically.

Numerical simulation method can be used to save Cost for mold repairing in the process of compensation and to reduce new product development cycle. A spring forward method, which uses the finite element method to calculate the amount of springback accurately, is proposed [5]. The process can also be used for rapid prototyping of new products [6]; but also its well suitable to make old parts which have to be rebuilt, like automotive parts whose dies are today out of service.

1.1 INCREMENTAL SHEET METAL FORMING (ISMF)

Several new metal forming techniques have been developed in the last few years due to advances in:

1) Computer controlled machining and
2) The development of toolpath postprocessors in CAD software packages.

One significant outcome of this technology is the ability to form asymmetric shapes at low cost, without expensive dies. In ISMF, the blank remains stationary and rigidly holds the sheet and forming occurs with the CNC control of the tool in a CNC mill. The toolpath code is feed in the machine and the machine forces the tool to move along the desired path. The tool which is in continuous contact of the sheet and controlled by the computer forces the plastic deformation of sheet layer by layer and result in the required shape.

1.2 DEFINITION

Incremental Sheet Metal Forming (ISMF) is a process which:

- is a innovative sheet metal forming process,
- has a solid, hemispherical forming tool,
- does not requires large, dedicated dies,
- consist a forming tool which is in continuous contact with sheet metal,
- has a tool that moves under control, in three dimensional space,
- can manufacture axis symmetric sheet metal shapes [1].

1.3 ELEMENTS OF INCREMENTAL SHEET METAL FORMING

Incremental Sheet Metal forming has four basic elements:

1) A sheet of material like aluminum, steel, brass etc 2) A blankholder for rigidly hold the sheet
3) A single point hemispherical forming tool,
4) CNC Control and tool path planning as shown in Fig 1.

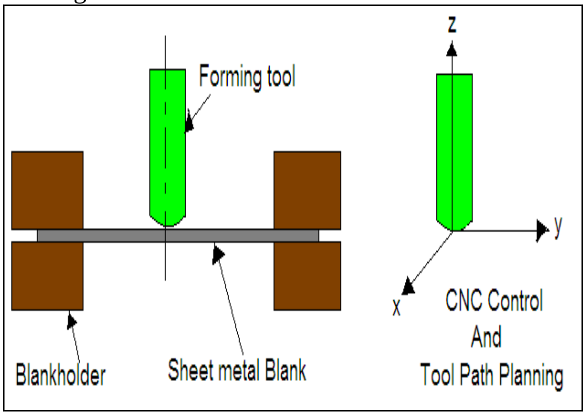

Figure 1: The basic elements needed for Incremental Sheet Metal Forming (ISMF)

1.4 TYPES OF INCREMENTAL SHEET METAL FORMING

ISMF is further categorized in two common types

1) Two Point Incremental Forming (TPIF)
2) Single Point Incremental Forming (SPIF)

These are discussed in the chronological order in which they appeared, historically. In TPIF, the blankholder moves vertically on the bearing i.e. along the Z axis, and at the same time forming tool pushes on to the sheet metal plate as shown in Fig 2. The process consists of two points where the sheet metal is pressed. Hence at a given time interval the sheet metal experiences forces at two points, therefore it is called two point incremental forming. One point is where plastic deformation occurs which is directly below the forming tool and the other point is a static post that creates a counter force on the sheet metal. At one point tool presses into the sheet and other act as a partial die. Hence TPIF is not purely dieless. TPIF consist of:

1) A sheet metal blank holder which moves down with the tool path increments.
2) A stationary post provided at the centre of the blank.
3) A forming tool
4) CNC programming.

To avoid the twisting of shape along the partial die and to provide the backpressure on sheet, there is a backing plate underneath the blank. The partial die in TPIF can also be replaced by a mould which acts as a full die.

In SPIF the opposite surface of the sheet being deformed is free and hence it is a pure dieless process. The apparatus of SPIF is simpler than TPIF as there is no stationary post and the blankholder remains stationary. But as the sheet is completely free from one side it creates different strain and stress patterns in the sheet, in comparison to TPIF.

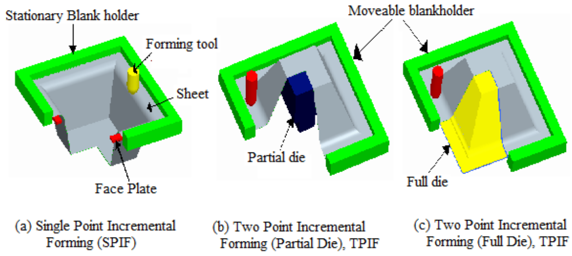

Figure 2: Types of Incremental forming

II. TOOLPATH GENERATION

Effective toolpath generation is very important for incremental forming. Normally two types of toolpath trajectory are used in incremental sheet forming as shown in Fig 3 and Fig 4. These are:

1. Contour toolpath
2. Spiral toolpath

2.1 Contour toolpath

Contour toolpath is defined by fixed step size increments (*dz*) between consecutive contours.

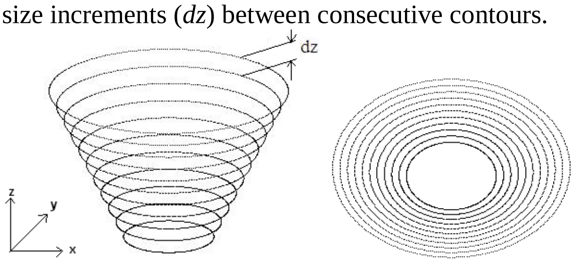

Figure 3: Contour Toolpath

2.2 Spiral toolpath

Spiral toolpath is continuous with incremental drop of the tool distributed over the complete contour of the part.

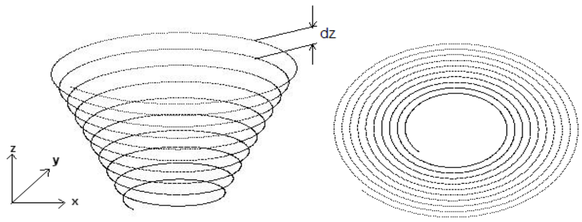

Figure 4: Spiral Toolpath

III. ACCURACY IN ISMF

There are three different types of error which affects the geometrical accuracy of the forming process. First includes the bending of sheet which occurs at the major base of the job. But this defect can be solved by using the backing plate which avoids the over bending of the sheet. Secondly when the tool moves from one part to the other part of the sheet, the sheet bounces back and this result in the distortion of the final shape of the part, this distortion is called springback. Third is a 'pillow effect' which occurs at the minor base of the job and represents the concave curvature on the undeformed material Micari [9]. All these defects are illustrated in Fig 5. Pillow effect can be overcome by just modifying the toolpath trajectory.

Out of the above three error, springback is the major error which effect the geometrical accuracy of part. Lack in geometrical accuracy is basically the difference between the ideal profile and obtained profile. To avoid the effect of springback, proper tradeoff should be made between various process parameters including the use of backing plate and definition of toolpath.

Three types of springback which exist in ISMF are:

- A continuous 'local springback' that occurs on every node at the displacement of the tool toward and away from the sheet element.
- A global springback that occurs at unloading and when the sheet is removed from the blankholder after the job has been made, this result in the change of final shape to some extent.
- A global springback which occurs when the job is trimmed or cut after the job is released from blankholder.

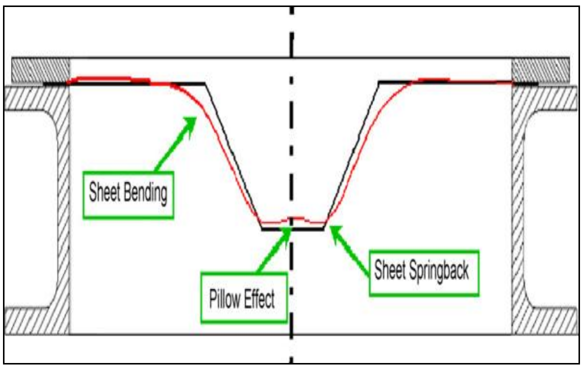

Figure 5: Geometrical error in SPIF process.

IV. FINITE ELEMENT MODELING

The FEA analysis was carried out using a variety of process parameters on CAD Software i.e. ABAQUS (version 6.10). The sheet used for model was Al5052 of young's modulus 70GPa and Poisson ratio 0.3, as Al alloy is the most commonly used in ISMF, mainly because of reduced forming forces as shown in Fig 6. The sheet size was of 75x75 mm and 100x100 mm and the other process parameters i.e. tool diameter (td) was 8 mm, 10 mm, 12.7 mm, the thickness of sheet for various simulation was 0.5 mm, 0.88 mm, 1.2 mm. The sheet was meshed in rectangular linear elements of 1 mm x 1 mm for all simulation. Three step down (dz) size were used i.e. 0.6 mm ,0.8 mm, 1 mm. Higher value of dz were avoided as it effect the surface roughness and lower value results in high simulation time [7] [8] [9] [10]. A truncated conical shape was taken for FEA simulation with the upper diameter of 65 mm and forming angle i.e. draw angle (α) for the two simulations was 45 and 60 degree. The higher value of draw angle was avoided as it leads to sheet thinning and cracks. The depth of cone for the simulation was taken to be 25 mm and 20 mm.

Reliable result was obtained for all simulation consisting of 5625 elements. The final model was cut along the X-plane and the displacement of each node was calculated from the simulation results. The result of all simulation was calculated and analyzed.

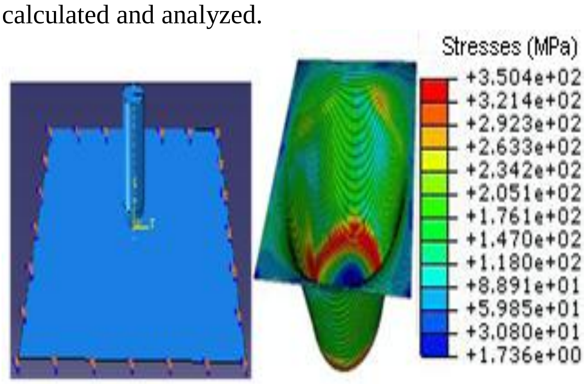

Figure 6: Initial and final stages of sheet metal simulation in ABAQUS

Springback analysis is generally composed of two steps: loading and unloading. The behavior of the nodes was studied with respect to the tool movement along the generated tool path. The displacement of tool towards and away from the sheet element results in the displacement of node, As shown in below Fig 7 and its was found that the crest and trough found in graph are due to the loading and bounce back of sheet which finally results in spring back

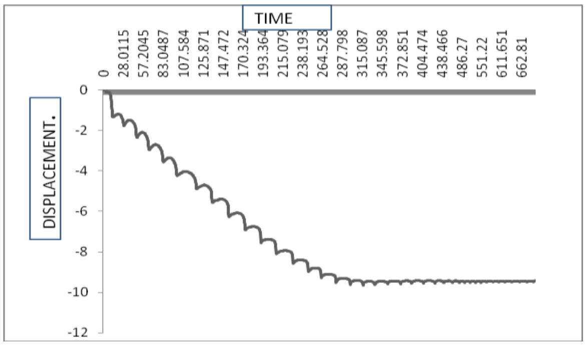

Figure 7: Displacement behavior of node with time

Springback in forming is of three types:
1) Local springback of sheet after force exerted by tool is removed. 2) Global springback, which changes the shape of sheet when it is unclamped and 3) springback which occurs when the sheet is trimmed or cut, if desired. In this paper the effect of various parameters on the local springback was studied. To calculate the local springback occurred in the model the node displacement result obtained from simulation was plotted with ideal curve generated from MATLAB and then the displacement was measured. Fig 8 shows the difference between the simulated and ideal curve.

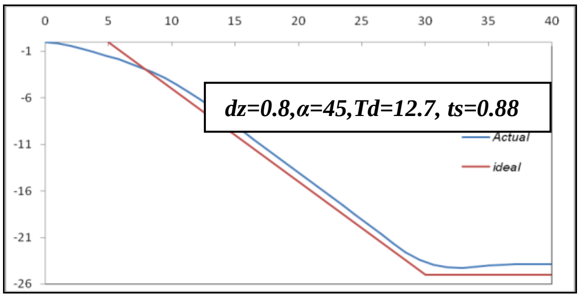

Figure 8: Comparison between ideal & simulated result

V. RESULT AND DISCUSSIONS

5.1 Influence of draw angle (α):

Draw angle has a direct effect on the thickness of sheet, as draw angle (α) increases, more decrease in sheet thickness. The simulation results for draw angle 45 and 60 degree corresponding to step size of 0.6 and 0.8 mm was compared and given Table 1. It was clear from simulation results that the springback increases with increase in draw angle.

Table 1: Local springback results for varied draw angle (α)

dz(mm)	***T_d(mm)***	***T_s(mm)***	***α***	***Springback (mm)***
0.8	12.7	0.88	45	0.7
0.8	12.7	0.88	60	1.4
0.6	12.7	0.88	45	0.64
0.6	12.7	0.88	60	1.3

5.2 Influence of tool diameter (T_d):

Tool diameter affects the surface quality and manufacturing time. The minimum diameter used depends upon the smallest radius required in the part. The most commonly used tool diameters are 12 and 12.7 mm [1]. Three simulations for tool diameter of 8 mm, 10 mm, and 12.7 mm were carried out and the springback obtained are shown in Table 2. It clearly indicates that increase in tool diameter, increases the springback.

Table 2: Local springback results for varied tool diameter (T_d)

dz(mm)	***T_d(mm)***	***T_s(mm)***	***α***	***Springback(mm)***
0.8	8	0.88	45	0.45
0.8	10	0.88	45	0.5
0.8	12.7	0.88	45	0.7

5.3 Influence of Step size (dz):

High value of Step size (dz) results in surface roughness and lower value results in longer simulation time. Therefore for the simulation test the preferable values of dz are 0.6, 0.8 and 1 mm are taken, and results corresponding to variation in step size for springback are shown in Table 3. It can be said that the value of dz has little effect on springback but it has much effect on surface quality.

Table: 3 Springback results for varied step size **(**dz**)**

dz(mm)	***Td(mm)***	***Ts(mm)***	***α***	***Springback(m m)***
0.6	12.7	0.88	45	0.64
0.8	12.7	0.88	45	0.7
1	12.7	0.88	45	0.75

5.4 Influence of Sheet thickness (T_s)

Thickness of sheet depends on the nature of job; it has a direct effect on the forming angle, higher sheet thickness is avoided as they require high forces for deformation. In ISMF, the thickness of sheet varies from 0.3 to 3 mm. In present study simulation on thickness of 0.5 and 0.88 were carried out and results corresponding to variation in sheet thickness for springback are shown in Table 4. It was observed that change in sheet thickness has less impact on variation of spring back.

Table: 4 Local springback results for varied sheet thickness **(**Ts**).**

dz(mm)	***Td(mm)***	***Ts(mm)***	***α***	***Springback(m m)***
0.8	12.7	0.5	45	0.4
0.8	12.7	0.88	45	0.5

VI. CONCLUSION

A study was carried out in order to evaluate the influence of various forming parameters on local springback in forming components. Based on simulation results, the local springback was calculated for different process parameter which include tool diameter (Td), Draw angle (α), step size (dz), and sheet thickness (Ts).The node displacement from simulation result were compared with the ideal curve geometry and it was obtained that springback increases with increase in tool diameter (Td), draw angle (α) and sheet thickness (Ts). The vertical step size (dz) has little effect on springback which increases with increase in dz, but higher value of incremental step size (dz) results in surface roughness and cracks. It is clear from present study that forming angle (α) has a major effect on the springback, and the geometrical accuracy of the formed part can be improved by making necessary tradeoffs between above parameters.

For future work a generalized mathematical formulation can be made between these parameters to indicate the springback and global springback can be investigated for different shapes and parameters like material, lubrication, tool rotation etc.

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