Single Point Incremental Forming using Hydraulic Support

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Abstract— Incremental sheet forming is an innovative process having ability to fulfill demands for customized sheet metal parts without using costly dies unlike traditional forming processes. However, shape deviation of formed parts is one of the drawbacks which need technological developments to use ISF on shop floor. Backdrawing, use of half dies and customized toolpaths are some of the techniques being worked out for reducing shape deviation but have some limitations. The present work investigates the hydraulic supports developed to reduce shape deviation of the non-axisymmetric parts formed through SPIF. Simulations were carried out with different geometries to check the effectiveness of the hydraulic support process. Results show a significant improvement in the parts formed using hydraulic support process over those formed without using it. This work gives another method for forming components with reduced bending. Also it proposes a new method of using hydraulic supports as flexible die which doesn't needs to be changed with the part geometry.

Key words: Single Point Incremental Forming (SPIF). Hydraulic Flexible Supports

I. Introduction

Rapid prototyping techniques like layered manufacturing [1] and ISF are being used for manufacturing customized parts which are the need of market today. The origin of ISF owes back to conventional sheet metal forming process of spinning where axis-symmetric parts are formed by pressing of sheet with a rotating mandrel and force is applied with the help of roller ended tool. The process of ISF differs from spinning because of its capability of forming non-axisymmetric parts whereby spinning can only form axisymmetric components. A metallic sheet clamped around the edges is suppressed by a tool which can be ball nosed or hemi spherically ended. Tool moves in X & Y direction causing localized plastic deformation of sheet. The trajectory followed by the tool is same as geometry required while with each contour tool descends down by small distance known as stepdown. Figure 1 explains the process of ISF.

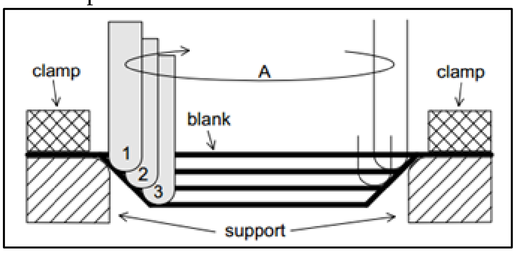


Fig. 1: SPIF as conceived by Iseki (1989) [2]

Solid models of the part to be formed are designed using CAD/CAM software which are also useful for generating toolpath according to the geometry designed [3]. Some of the advantages of ISF include its flexibility of using same machine and tool facilities for manufacturing wide range of products. For small batch manufacturing, cost of product is reduced as dies are omitted in this process [4]. Forming forces applied for localized deformation are not so high unlike conventional process of deep drawing [5]. Higher formability limits can be achieved because of localized deformation yielding higher amount of material [6]. Some limitations of this process are forming forces may have to be assessed for forming complex parts to ensure safety of tooling and equipment's used [7], achieving vertical walls, uneven thinning of sheet material and geometric accuracy of parts etc.[8].

II. Literature Review

Any sheet metal part formed is useful when it's manufactured within the tolerances limits. Some of the defects causing shape deviation of parts include bending of sheet near the clamped periphery, springback, pillow effect etc. [9]. A study of FEM for geometric accuracy of parts in ISF was presented considering various shell element formulations [10]. Some of the earlier works done in this direction are mentioned in the following lines.

In majority of works backing plate is used to support the unclamped region of sheet. An elastic rubber tool was used by Tanakka et al. for supporting sheet. Back drawing is another good approach in which sheet once formed is flipped around its axis and the same tool path is used to suppress back the region of the sheet undergone bending. An important application of this technique can be seen in case where any kind of supports cannot be used below the sheet [9]. One of the commonly used techniques is using a half die which is the replica of shape or geometry to be formed. Besides supporting the sheet it also guides the deformation of sheet eliminating chances of undesired bending [11]. Duplex forming is also used to form complex geometries without shape deviation. In this two tools are used in which one above the sheet deforms it, while the one below the sheet acts as dynamic die supporting it [12]. A different method proposed by Franzen et al. was using a Dyna-Die which minimizes shape deviation but can only form axisymmetric parts [13].

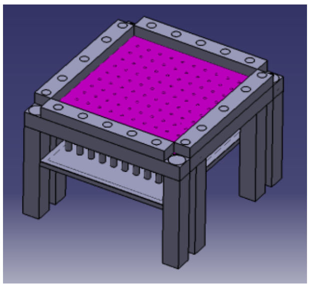
The solutions mentioned above have some or the other limitation as process like backing plate and half die are not flexible because of their dependency on shape formed. Backdrawing is a good approach but is a post processing operation as it allows the sheet to bend and then rectify it which increases processing time. Limitation with TPIF is requirement of specially designed machines and it cannot be used with normal CNC machines. Therefore, a solution is required which has following features:

– It is flexible enough to accommodate the changes in shape of part.
– It should be a pre-processing operation which will save time unlike backdrawing.
– It can be used with normal CNC machines which are easily available instead of designing especially dedicated machines like one used in TPIF.

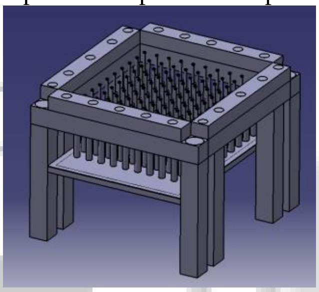
The present research work deals with reduction of bending of sheet in SPIF process which enables us to form complex parts with near to desired geometric accuracy.

III. METHODOLOGY

Hydraulic Flexible die attached to fixture and the setup is developed (as shown in Figure 2). Hydraulic supports can be rearranged repeatedly in up and down direction to support various geometries. To avoid any chances of hydraulic supports penetrating sheet or causing dents on sheet surface the tip of hydraulic support were fitted with rubber caps which increase the supporting area. It also acts as a cushioning effect for the sheet.



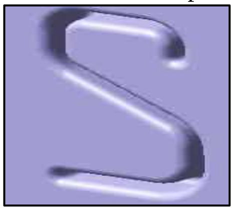
(a) Proposed Setup with clamped Sheet



(b) Proposed Setup without Sheet Clamped

Fig. 2: (a) CAD model of proposed setup

Two non-axisymmetric shaped geometries were selected for investigation. Figure 3 shows 3D CAD model of S and 9 shape geometries made by using CATIA V5R20. Toolpath was generated using CAM software LS DYNA. Forming tools of diameter 8 mm were used for S and 9 shape respectively. Al1050 i.e. aluminium alloy was used as sheet material having thickness of 0.95mm. For reducing the friction between sheet and tool hydraulic oil grade 68 was used. Table 1 shows the specification of parts formed.



(a)

(b)

Fig. 3: CAD model of (a) S shape (b) 9 shape

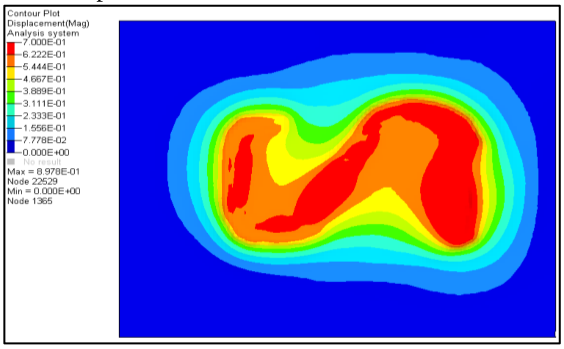
Geometry	S shape	9 shape
Depth (mm)	30	30
Wall angle (degrees)	60	60

Table 1: Specifications of geometries

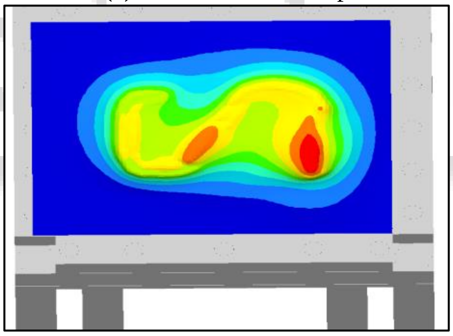
IV. RESULTS AND DISCUSSIONS

CAE software package LS Dyna was used for simulation of the S and 9 shape. The simulations were conducted under two conditions that is firstly the simulations were carried with the conventional setup and secondly the simulation were carried with the proposed setup of the flexible hydraulic support setup. For both the shapes along with the two conditions the displacement pattern and Von Mises stress were simulated and following results were obtained.

The displacement pattern of the S and 9 shape showed similar results. ISF performed on conventional setup showed more uneven displacement pattern to that of that performed on the proposed setup of flexible hydraulic supports wwhich is clearly evident from the Figure 4.1 (a) shows contour plots displacement results for S shape 3D CAD model with geometry formed using conventional setup without hydraulic supports, while Figure 4.1 (b) shows contour plots displacement results for S shape 3D CAD model with geometry formed using flexible hydraulic supports setup.



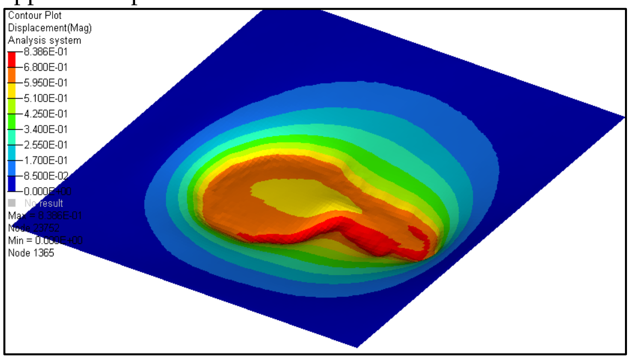
Uneven displacement pattern
(a) Conventional Setup



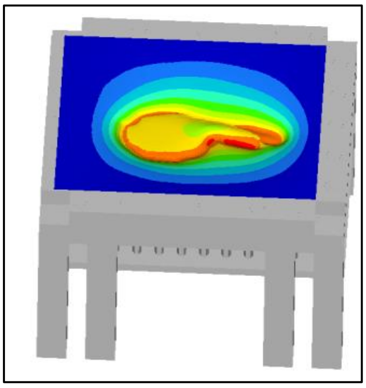
Even displacement pattern
(b) Flexible hydraulic support Setup

Fig. 4.1: Contour plots displacement results with formed parts of S shape

Figure 4.2 (a) contour plots displacement results for 9 shape 3D CAD model with geometry formed using conventional setup without hydraulic supports, while Figure 4.2 (b) contour plots displacement results for 9 shape 3D CAD model with geometry formed using Flexible hydraulic support Setup.



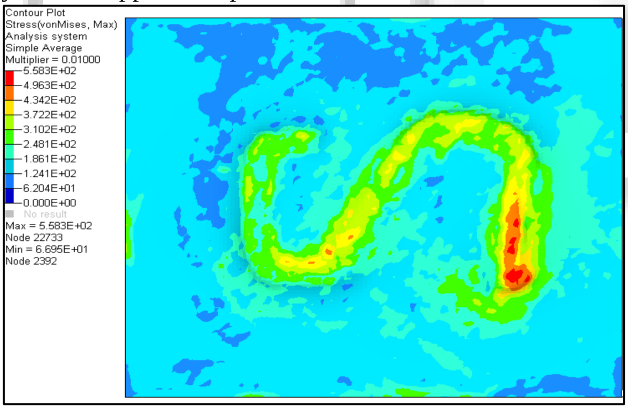
(a) Conventional Setup (Uneven Displacement Pattern)



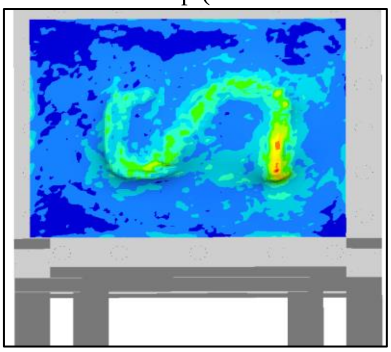
(b)Flexible hydraulic support Setup (Even Displacement Pattern)

Fig. 4.2: Contour plots displacement results with formed parts of 9 shape (a) Without supports (b) With hydraulic supports

For ISF of shape S the Von Mises stress generated were of the order of 496 MPa for the conventional setup and for the proposed setup the Von Mises stress were of the order of 248 MPa. It is clearly evident from the data obtained during simulation that around 50% of the stress generated during the ISF can be reduced by using the flexible hydraulic support setup .Figure 4.3 (a) shows contour plots Von Mises Stress results for S shape formed using conventional setup without hydraulic supports, while Figure 4.3 (b) contour plots Von Mises Stress results for S shape formed using Flexible hydraulic support Setup.



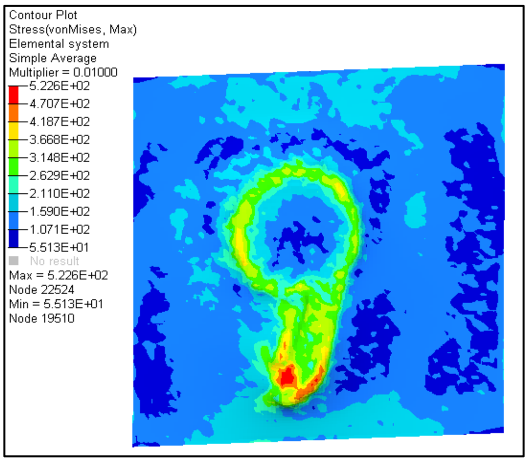
(a) Conventional Setup (Max Stress 496 MPa)



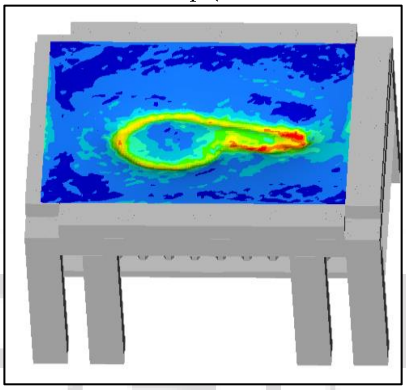
(b) Flexible Hydraulic Support (Max Stress 248 MPa)

Fig. 4.3: Contour plots Von Mises Stress with formed parts of S shape

Similarly for the shape 9 the Von Mises stress generated for the conventional setup were of the order of 470 MPa and for the proposed setup it is of the order of 218 MPa. It is clearly evident from the data obtained during simulation that stresses could be reduce to 53.62% by using the flexible hydraulic support setup. Figure 4.4 (a) contour plots Von Mises Stress results for 9 shape formed using without hydraulic supports, while Figure 4.4 (b) contour plots Von Mises Stress results for 9 shape formed using hydraulic supports.



(a) Conventional Setup (Max Stress 470 MPa)



(b) Flexible hydraulic support setup (Max Stress 218 MPa)

Fig. 4.4: Contour plots Von Mises Stress results with formed parts of 9 shape

V. CONCLUSIONS

A fixture was developed incorporating the mechanism for holding hydraulic supports which supported the sheet while forming is carried out. The parts formed using the proposed mechanism show betterment over the parts made by SPISF. Shape deviation analysis for S and 9 shape shows reduction of bending of sheet near to the point where tool takes sharp turns. Simulations study sgowed that a even displacement pattern could be obtained and the Stress could atleast be reduced to half of the usual values.

Forming non axisymmetric parts through SPIF is tedious because of the tools used like backing plate, clamping near to the boundary of the geometry etc. These tools have to be changed with the geometries and are not flexible. Thus, these drawbacks overcomes the advantages of ISF over conventional methods using dies and reducing the utility of ISF. The methodology mentioned in this work provides an important solution to the problem cited above and can be used as a flexible die which works with different geometries.

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