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A NUMERICAL INVESTIGATION ON FORMING BEHAVIOUR OF HOMOGENEOUS BLANKS DURING SINGLE POINT INCREMENTAL FORMING PROCESS

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ABSTRACT

Single Point Incremental Forming (SPIF) process is one of the advanced forming techniques that industry has nowadays. Improved formability is one of the major advantages of the process. However, it is associated with limitation such as thinning of blank and poor geometrical accuracy of the formed part. In this study, forming behaviour of homogeneous blanks during the SPIF process has been investigated. A simulation study has been carried out using ABAQUS/Explicit. Effect of change in thickness, yield strength, strain index and strength coefficient of blank on responses like Plastic Equivalent Strain (PEEQ), percentage of thinning and geometrical accuracy of formed component has been evaluated. It has been found that change in the thickness has major effect on PEEQ and geometrical accuracy. Regarding percentage of thinning, change in the yield strength of blank is found to be majorly affecting.

Keywords: *Single Point Incremental Forming, Thinning, ABAQUS/Explicit, Formability and Geometrical Accuracy.*

1. Introduction

Lot of efforts have been made by the researchers to develop new forming technologies particularly for the automobile and aerospace industries. As a result, researchers have yielded at Single Point Incremental Forming (SPIF) process. Figure 1 represents the working principle of the SPIF process.

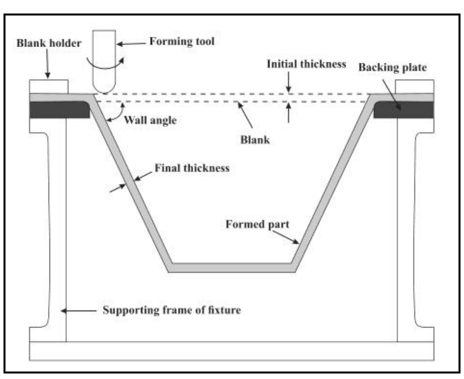

Fig 1. Schematic of Single Point Incremental Forming (SPIF) process

In this process, localized deformation is provided with the help of a hemispherical or spherical tool [1]. The path of the tool depends upon the target geometry. Due to the localized deformation, the formability of the blank is better [2, 3] and the force requirement is low in comparison to the conventional forming processes. However, the process is very time consuming and it is associated with the limitation of spring back and thinning [4].

There are many process parameters associated with this process such as tool feed (mm/sec), tool rotational speed (Rotation Per Minute, RPM), tool type, incremental depth (mm), wall angle (degree) and tool path strategy. For a given tool path strategy and wall angle, the quality of part produce from SPIF process depends upon above mentioned parameters. The researchers generally investigate the responses such as geometrical accuracy, surface finish [5] and thinning in the formed part. It has been observed that as the wall angle increases the thinning of the blank increases [2]. Apart from the process parameters, lubrication between blank and tool also plays a vital role on the surface finish of the formed part [6]. Regarding the surface finish, dummy sheet can be used between tool and blank to avoid the direct contact which will lead to improve the surface finish of the formed component [7]. SPIF has many applications such as die making [8] and few applications in medical industries [9, 10].

The forming behaviour of homogeneous blanks can be studied using any simulation tool which yields in saving of time, cost and material. ABAQUS/Explicit can be used for the mentioned purpose and it has been found to be resulting is acceptable results [2].

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So, in the present investigation, ABAQUS/Explicit is used as a simulation tool. Simulation of SPIF process has been done to form a truncated cone. The effect of material parameters and blank thickness on responses like %thinning, Plastic Equivalent Strain (PEEQ) and geometrical accuracy of formed part has been reported.

2. Simulation Conditions

Different simulation and boundary conditions are discussed in the next sections. In addition to that the material properties considered for the simulation purpose are reported.

2.1 Materials

In the present simulation study, SPIF process has been investigated for the homogeneous blanks. Total four different blanks having different properties are formed using the SPIF process. The thickness and material properties of the four different materials are indicated in the table 1. It has been assumed that all the material considered for the simulation follows the Power-Law equation. The constant properties are density of the material 2.680 X 10^{-6} kg/mm^3, Poisson's ratio 0.3 and Young's modulus 70300 MPa.

Table 1. Material thickness and properties

Material	Thickness (mm)	Yield Strength (MPa)	Strain Index	Strength coefficient (MPa)
A	2	200	0.125	300
B	1.25	200	0.125	300
C	2	150	0.125	300
D	2	200	0.100	300
E	2	200	0.125	250

2.2 Process conditions

Forming of all the different blanks was done using the SPIF process. During the SPIF process some of the process parameters were kept constant as represented in table 2.

Table 2. Constant process parameters of SPIF

Sr. No.	Parameter	Unit	Value
1	Tool feed	mm/sec	15
2	Coefficient of friction between blank and tool [11]	-	0.1
3	Incremental depth	mm	0.5
4	Wall angle	Degree	45
5	Tool rotational speed	RPM	1000
6	Truncated Cone height	mm	20
7	Top diameter of truncated cone	mm	50

A truncated cone was formed using a hemispherical tool of 6 mm radius. The blank dimensions were kept as 70 x 70 mm^2. The tool was modelled as rigid body and the blanks were modelled as shell deformable body.

2.3 Boundary Condition

The assembly of SPIF tool and blank is represented in the figure 2. The blank edges were fixed in order to achieve the pure stretching conditions. The tool path strategy adopted was outward to inward radial tool movement. During the forming process the tool radius compensation was not considered.

Meshing of the shell deformable blank was done using S4R linear quadrilateral element [2] using 0.5 mesh size. As the SPIF tool was considered as rigid body, meshing was not required for it.

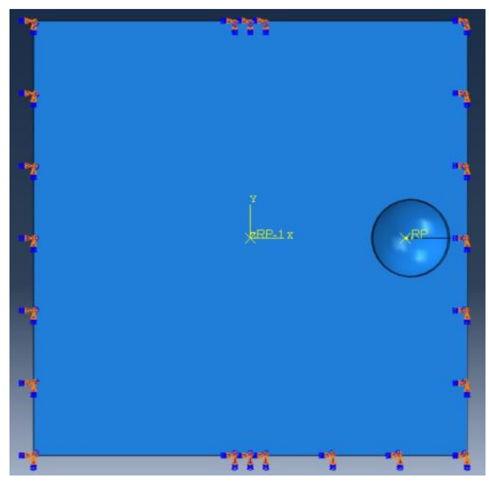


Fig 2. Assembly of tool and blank

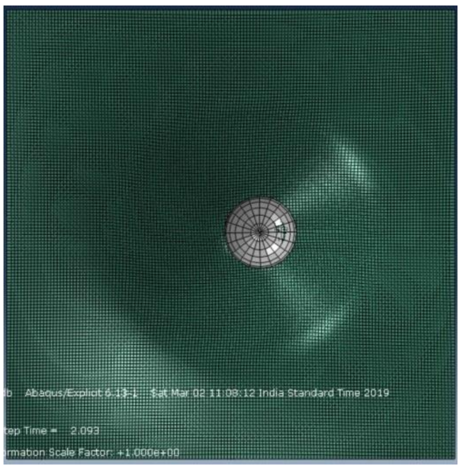
3. Results and Discussion

3.1 Formed Component

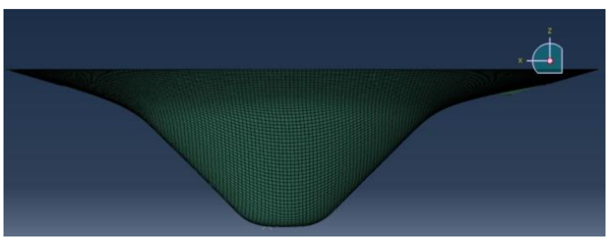
The tool was given the planner movement in XY plane and blank was deformed in the direction of thickness. Figure 3 indicates the formed component using the SPIF process in ABQUS/Explicit. After the successful completion of all the simulations, results such as plastic equivalent strain (PEEQ) and thinning of blank were investigated. In order to study the geometrical accuracy, formed geometry was also compared with the target geometry for all the different materials.

3.2 Thinning

In order to investigate the effect of change of each parameter, results of material A are considered as reference. The results of materials B, C, D and E are compared with results of material A and accordingly the observations are done.



Top view



Side view

Fig 3. Formed component

Figure 4 represents the thinning of blank C after the forming process has been completed. For material C, the thinning of blank can be observed at tool initial position in figure 4. When the tool comes at its starting position after completing the planner movement, it deforms the blank and because of that the blank experience excessive thinning at this particular location. For material C, the initial blank thickness was 2 mm and after forming final thickness was 0.864 mm which means that there was 56.8% of thinning occurred in the blank. Similarly, for different materials, %thinning was investigated and the results are represented in the table 3.

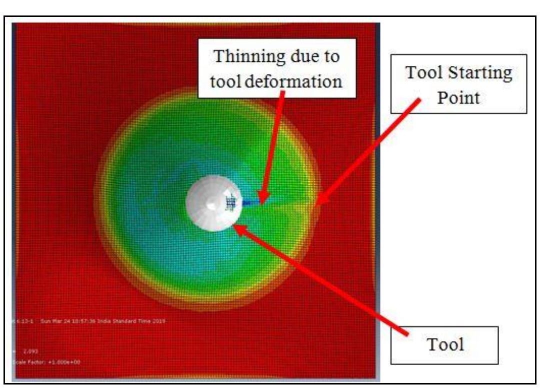


Fig 4. Thinning in the formed component for material C (minimum thickness 0.864 mm and original thickness 2 mm) – 56.8% thinning

Table 3. Thinning results for different materials

Material	A	B	C	D	E
% Thinning	53.5	52	56.8	55.05	52.86
Deviation from Material A	-	1.5	3.3	1.55	0.64

From table 3, on comparing the %thinning results of all material with results of material A, it can be noted that the %thinning is highest for material C and minimum for material B. This indicates that decrease in the yield strength of material will result in more thinning or in other words thinning during the SPIF process is more affected by the change in the yield strength of the material in comparison to change in thickness, strain index and strength coefficient. Yield strength represents the level of stress at which material will start deforming. If the value of yield strength decreases that means that material is easy to deform. For a particular load it will deform excessively and that will lead to more thinning of the blank during forming process. This is the reason why material C has maximum %thinning.

3.3 PEEQ

After the completion of simulations, result of PEEQ was extracted which indicates the permanent strain remained in the blank after the forming process has been completed. Figure 5 indicates the PEEQ in material C after the forming process. The maximum plastic strain can be observed near the tool starting position because at that place more deformation is experienced by the blank.

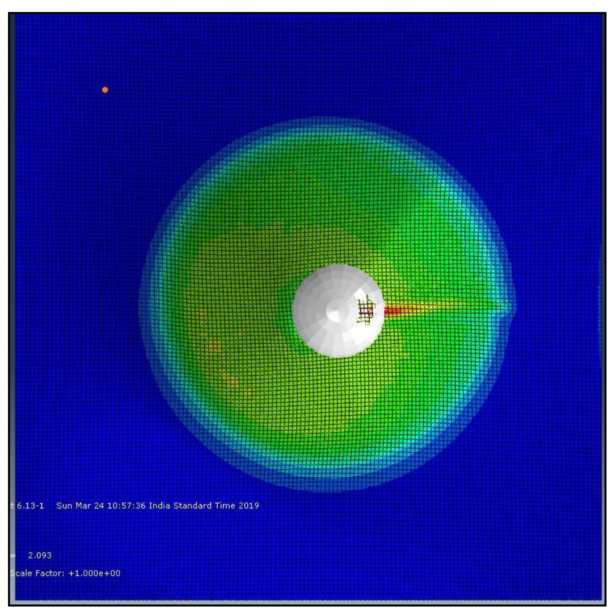


Fig 5. PEEQ in the formed component for material C – maximum PEEQ observed was 2.87

Table 4. PEEQ results for different materials

Material	A	B	C	D	E
PEEQ	2.87	2.30	2.87	3.05	2.84
Deviation from Material A	-	0.57	0	0.18	0.03

Table 4 indicates the results of PEEQ for all the materials along with deviation of results from material A. From table 4, it can be observed that the maximum and minimum PEEQ is observed for material D and B respectively. But, on comparison with the results of material A, it can be noted that the maximum deviation is for material B. This represents that PEEQ is significantly affected by the change in thickness of the blank during the SPIF process in comparison to the change in yield strength, strain index and strength coefficient. The less amount of plastic strain indicates less formability of the blank and which may be due to the reduction of the thickness value.

3.4 Comparison of formed geometry

All the formed geometries for different materials are compared with the formed geometry for material A as depicted in figure 6. It can be observed that maximum mismatch with formed geometry of material A is for material B followed by material C, D and E. It indicates that the effect of change in thickness on geometrical accuracy is highest in comparison to the effect of change in yield strength, strain index and strength coefficient. The formed geometry of material E is exactly matching with the formed geometry of material A. The deviation from formed geometry of material A for all the materials is represented in table 5.

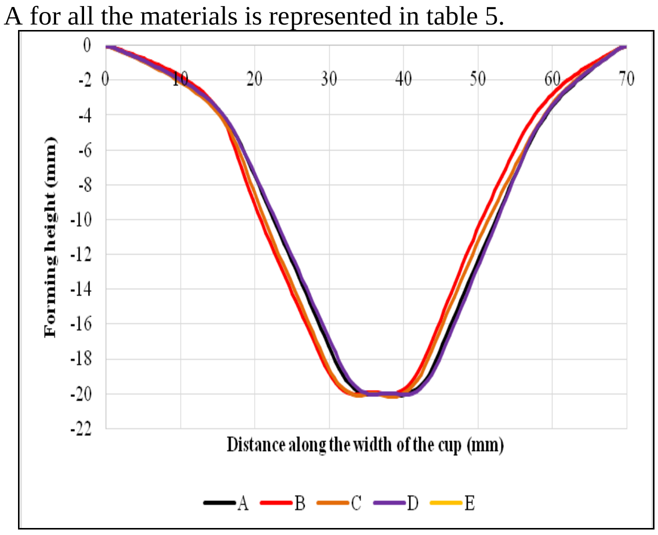


Fig 6. Comparison of formed geometry

Table 5. Deviation of formed geometry from formed geometry of material A

Material	B	C	D	E
Deviation	2.03	1.45	0.70	0.65

From table 5, it can be noted that the geometrical accuracy achieved in the SPIF is majorly affected by the thickness of the blank. Decrease in the thickness makes the blank weaker and that reduced the load bearing capacity of the blank. This will affect the formability of blank. This is the reason why the deviation of formed geometry of material B from material A is high. In addition to that strain index and strength coefficient have negligible effect on geometrical accuracy of the formed component using SPIF process.

4. Conclusion

In the present simulation study, investigation on forming behavior of homogeneous blanks was done. Effect of change in thickness, yield strength, strain index and strength coefficient of blank on the responses like percentage of thinning, PEEQ and geometrical accuracy was studied. Following points can be concluded from the study:

i. Thinning of the blank is one of the major limitations of the SPIF process. More thinning is observed at tool initial position due to the incremental deformation provided by the tool.
ii. Yield strength has maximum effect on thinning of the blank during the SPIF process in comparison to the effect of thickness, strain index and strength coefficient of the blank.
iii. Change in the thickness of blank has the major effect on the PEEQ experienced by the blank during the SPIF process in comparison to the effect of yield strength, strain index and strength coefficient of the blank.
iv. Geometrical accuracy is also one of the major concerns of SPIF process. Regarding that it was found that change in the thickness of blank has major effect on the geometrical accuracy. Strain index and strength coefficient ratio have negligible effect of geometrical accuracy achieved in the SPIF process.

References

1. Desai B V, Desai K P and Raval H K, (2017) “The performance of tool shape on efficiency and quality of forming in incremental sheet-forming process”, International Journal of Rapid Manufacturing, vol:6(4), 215-234.

2. Filice L, Fratini L and Micari F, (2002) “Analysis of material formability in incremental forming”, CIRP Annals-Manufacturing Technology, vol:51(1),199–202.

3. Centeno G, Bagudanch I, Martínez-Donaire A J, Garcia-Romeu M L and Vallellano C (2014), “Critical analysis of necking and fracture limit strains and forming forces in single-point incremental forming”, Materials & Design, vol:63, 20-29.

4. Arfa H, Bahloul R and BelHadjSalah H (2013), “Finite element modelling and experimental investigation of single point incremental forming process of aluminum sheets: influence of process parameters on punch force monitoring and on mechanical and geometrical quality of parts”, International journal of material forming, vol:6(4), 483-510.

5. Desai B V, Desai K P and Raval H K (2014), “Die-Less rapid prototyping process: Parametric investigations”, Procedia materials science, vol: 6, 666-673.

6. Azevedo N G, Farias J S, Bastos R P, Teixeira P, Davim J P and De Sousa RJA (2015), “Lubrication aspects during single point incremental forming for steel and aluminum materials”, Int J Precis Eng Manuf, vol:16:589.

7. Martins P A F, Bay N, Skjødt M and Silva M B (2008), "Theory of single point incremental forming", CIRP annals, vol:57(1), 247-252.

8. Bens J, Van Mieghem B, Appermont R, Vanhove H, Van Bael A, Duflou J and Ivens J (2012), "Development of material and energyefficient metal sheet based tools for composite manufacturing", Proceedings 15th European Conf. on Composite Materials, ECCM, Venice

9. Lu B, Ou H, Shi S Q, Long H and Chen J (2016), "Titanium based cranial reconstruction using incremental sheet forming", International Journal of Material Forming, vol:9(3), 361-370.

10. Duflou J R, Lauwers B, Verbert J, Gelaude F and Tunckol Y (2005), "Medical application of single point incremental forming: cranial plate manufacturing, virtual modeling and rapid manufacturing", Proc. 2nd Int. Conf. on Advanced Research in Virtual and Rapid Prototyping, 161–66.

11. Saidi B, Boulila A, Ayadi M and Nasri R (2015), "Prediction of the friction coefficient of the incremental sheet forming SPIF", The 6th International Congress Design and Modelling of Mechanical Systems CMSM'2015.