Geometrical Study of Channel Profile under Incremental Forming Process: Numerical Simulation

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ABSTRACT

Incremental forming is one of the innovative manufacturing technologies in plate sheet forming techniques. With the incremental forming process, plate formation can be as desired and also easily applied to the manufacturing with a limited number of products. This paper is conducted to find out the smallest geometry of deviation between the design with the results of the process and the best step-down selection using a single point incremental forming (SPIF). The variable variations used in this research was 2-6 (mm) of step-down where this process uses a punch tool in the form of a hemispherical / half ball and with 2 clamps. Numerical simulation method with explicit finite element model was used as a virtual experiment with the helical shaped tool movement. The tool moves to form a blank with a size of 12x160x200 mm into a channel profile with a speed of 8 mm/s. The result showed that the deviation between the product and the design has increased from step down 2-6 mm. The smallest deviations were 3.63 mm for x axis and 12,549 mm of total depth or 4.57% for y axis with 2 mm step down parameter. Whereas for step down 4 mm had the deviation of 3.9 mm and 13.853 of total depth. But for step down 6 mm had failed / damaged.

Keywords: *Incremental Forming, ANSYS/LS-DYNA, Step Down, Channel Profile, Geometry.*

Introduction

The structural components are very widely used in the automotive field, especially channel profile which been found on the frame of the car roof. Generally, an automotive sector is always related to manufacturing processes

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that are always developing at any time. In most manufacturing processes, prototyping is a very important step before starting real operations in production. Prototype enables product improvement and development, changing designs in the initial steps of product development. In the 2000's, one of the innovative solutions in manufacturing technology was developed, namely the incremental sheet metal forming process [1]. One of the applications of Incremental Sheet metal forming is a single point incremental forming (SPIF), which is part of the production process wherein the manufacturing process uses one punch tool that is able to form the desired product from the sheet incrementally. One of the main problems in the process of establishing the SPIF method is the accuracy that depends on the application of process parameters [2].

Wikanda et al. [3] conducted a study using SPCC 270 material and Aluminum Alloy with single point incremental forming (SPIF) method with 4 clamps. The data retrieval process used a 3D scanning engine while the measurement of deviation with the comparison method. Comparison between SPIF process products and generic 3D CAD models used the Geo-Magic Qualify 2013 software. Martins et al [4] conducted a theoretical analysis by obtaining the deformation when performing a single point incremental forming. The shape was like a square container with aluminum material AA1050-H111. Bagundach et al [5] conducted research to determine the estimated forces received by plate sheets during the formation process. The variations used are wall angle with single point incremental forming method. Durante et al. [6] varied the rotational speed of the tools with the pyramid frusta path to find out the roughness caused by the friction of the tool speed and the plate sheet. Grim et al [7] conducted a study using variations of tool geometry and many directions during the incremental forming process so as to increase smoothness, profile accuracy and easy to form. Mashudi et al [8] studied geometry formation using curved tip-shaped chisels with spiral trajectories where the results were able to produce flange height.

This paper aims to determine the deviation in geometry between product design and results in the form of channel profiles and step-down selection that corresponds to the single point incremental forming process.

Methods

In carrying out this research, it is necessary to have appropriate stages in order to achieve the desired results as shown in Figure 1. The model of the specimen to be tested is blank to form a channel profile which uses a hemispherical punch tool. The model of the specimen to be tested is blank to form a channel profile which uses a hemispherical punch tool. The dimensions of the blank part was 0.88x160x200 mm, with the product specimen form 12x160x200 mm. While the tool size used is Ø 10x100 mm as shown in Figure 2 and Figure 3.

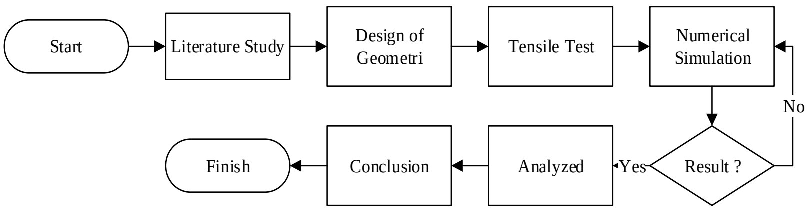


Figure 1: Flow Chart

A helical shaped groove method was used on SPIF which is a plot or line twisting forward in a field, can be seen in Figure 4. Numerical simulation used step down variations 2 mm, 4 mm and 6 mm so that the product with channel profile has a depth of 12 mm.

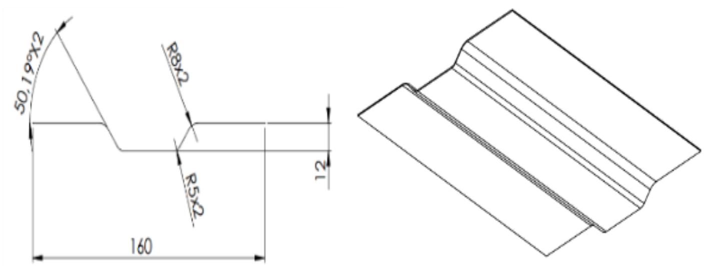


Figure 2 : Specimen design

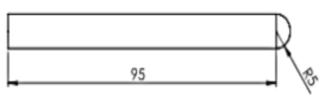


Figure 3 : Tool

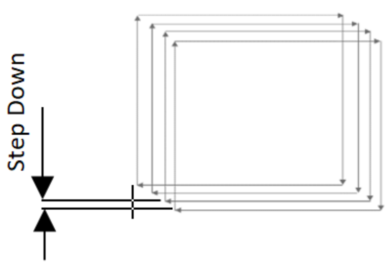


Figure 4 : Flow of a helical shaped tool path

Material

The material was aluminum which is sold on the market with a thickness of 0.88 mm. Material plate (blank) is tested first to determine the strength of the material, the machine used is Universal Testing Machine (UTM) with a capacity of 200 KN with ASTM E8 / E8M testing standards [9]. In Figure 5 shows the results of the tensile test where Young's modulus is 71 GPa, poisson's ratio is 0.33 yield strength is 79.34 MPa.

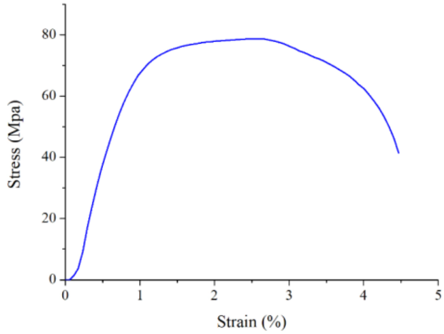


Figure 5 : Stress vs Strain Plasticity

Numerical Simulation

In conducting SPIF analysis, the method used is an explicit finite element method with the help of ANSYS/LS-DYNA. The helical path of tool is modeled as the x and z axes, while the step down variable is modeled as the y axis so that the depth reaches 12 mm as shown in Figure 6. The tool will experience contact with the aluminum plate so that the friction coefficient is 0.16.

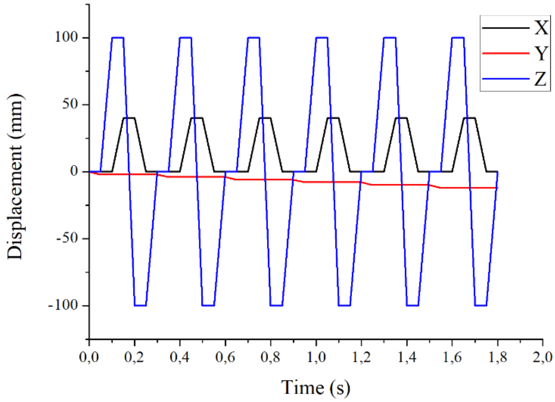


Figure 6 : Tool movements in 2 mm of step down

For boundary conditions such as fixed support were modeled on the part affected by blank-holders and dies that are rigid as shown in Figure 7. The size of the meshing was made of 2 mm for the blank sheet in Belytschko-Tsay element shell.

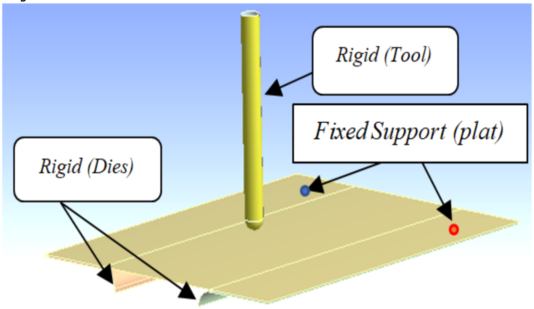


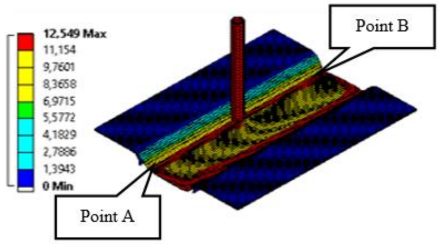
Figure 7 : Boundary Condition

Results and Discussion

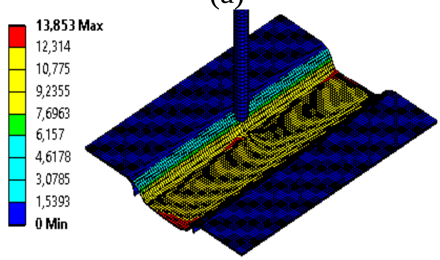
The explicit finite element method presented the results of the deformation of the single point incremental forming process where the step down variable is used. The maximum depth (y-axis) that can be generated for step down 2, 4, 6 (mm) sequentially is 12.549 mm, 13.853 mm and 38.413 mm as shown in Figure 8. From these results, if from a depth deformation design of 12 mm, then the difference between the products produced reached 4.57 % for step down 2 mm, 15.44 for step down 4 mm and it was ascertained that the conditions for step down 6 mm experienced product damage of 220.11% as shown in Table 1.

Table 1: Maximum depth

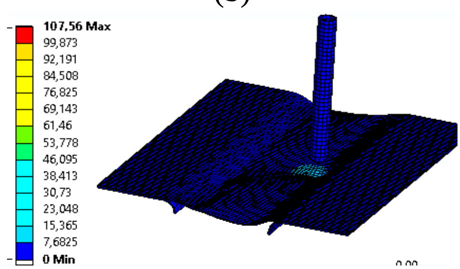
Step down (mm)	Maximum depth (mm)	Error from design (%)
Design	12	0
2	12.549	4.57
4	13.853	15.44
6	38.413	220.11



(a)



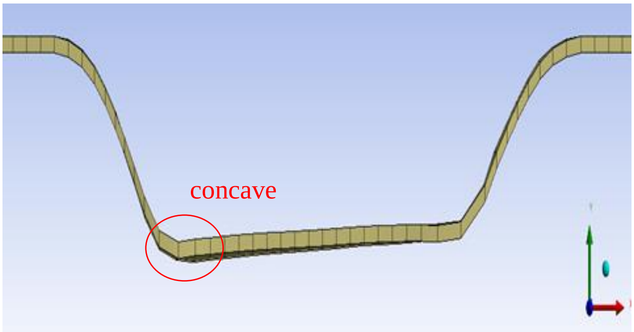
(b)



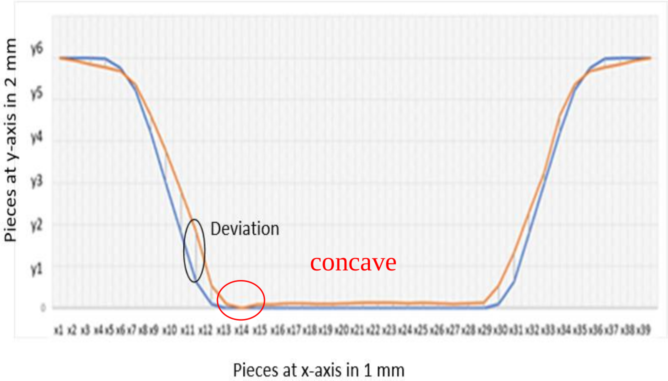
(c)

Figure 8 : SPIF simulation results of step down; (a) 2 mm; (b) 4 mm; (c) 6 mm

In addition to depth, it was also necessary to deviation between design with the products produced on the x-axis for several pieces where there are 5 pieces starting from areas A to B (Figure 8a). Measurements for the geometry difference on the x-axis were carried out every 2 mm on the y axis as shown in Figure 9. The images show the shape of the end of the product where there is a concave pattern on the left end. Figure 9a was processed with the help of CAD software which aims to obtain a line pattern as shown in Figure 9b. The deviation in maximum deformation on the x axis for step down 2 mm and 4 mm sequentially were 3.63 mm and 3.9 mm as shown in Figure 10. Whereas for step down 6 mm as previously described, the product was damaged. Comparison of depth (y axis) and x axis between designs with SPIF results), product results with 2 mm step down showed better results.



(a)



(b)

Figure 9 : Cross section profile : design = blue colour; product of SPIF = red colour

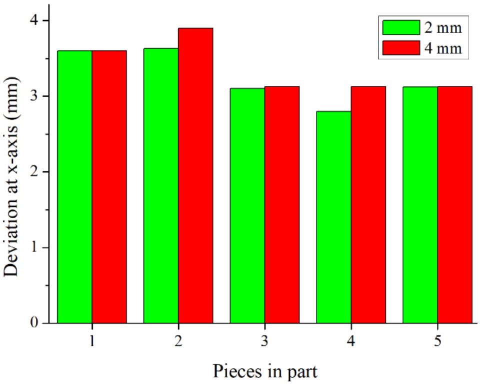


Figure 10 : Deviation between design with simulation

Evaluation of Spring Back

The deviation between the desired design and the SPIF product results through virtual experiments could occur due to spring back from the elasticity of a material. To find out from spring back, the results of the phenomenon are evaluated as shown in Figure 11.

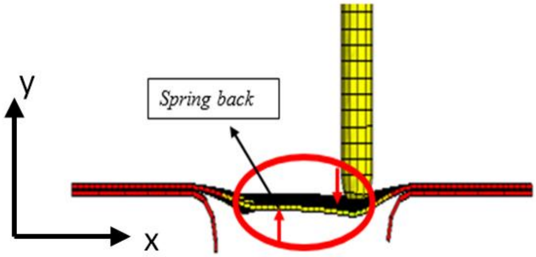


Figure. 11 : Spring back phenomenon

The spring back phenomenon will affect the accuracy of the geometry on the product. In this process at point B is the area in spring-back's observation as shown in Figure 8a. In this evaluation process, parameters such as the initial radius (Ri) and end radius (Rf) are needed to get the spring back coefficient using Equation (1) [10].

$$ks = \frac{R_i + \frac{t}{2}}{R_f + \frac{t}{2}}, R_i > R_f \quad (1)$$

Where : ks = Spring back factor; Ri = Initial radius (mm); Rf = Final radius (mm); t = Plate thickness (mm)

If the value of Ks = 1 then there is no spring back. Whereas if the value of Ks = 0 then the elastic recovery is perfect [11].

This evaluation was carried out on the area of the product that has a radius size with a spring back (ks) coefficient shown in Table 2. At 2 mm of step down with a depth deformation of 2 to 12 mm, the ks value is 0.717-0.888. This showed that the greater the depth value, the product would experience a decrease in the spring back coefficient. This was also experienced by the SPIF results with a 4 mm of step down. But when viewed on step down parameters, for 12 mm deformation, it had increased 1 mm and 2 mm for step down 2 and 4 mm. This shows the tendency of plastic properties at step 2 mm compared to 4 mm of step down.

Table 2 : Spring back (ks)

Step Down (mm)	**δ (mm)**	**Ri (mm)**	**Rf (mm)**	**ks**
2	2	30	42	0,717
	4	24	32	0,750
	6	18	22	0,818
	8	10	12	0,833
	10	8	10	0,800
	12	7	8	0,875
4	4	18	26	0,692
	8	14	18	0,778
	12	10	12	0,833

Note : δ = deformation

Conclusion

The SPIF process had been carried out by making channel profile products using numerical simulations which compare the geometry of the cross section between the design and the results of the incremental forming process. Variables were used step down 2 to 6 mm with depth (y axis) to reach 12 mm. Step down 2, 4, and 6 mm sequentially experienced a depth increase of 4.57%, 15.44% and 220.11% or failed (damaged). So that for the x axis, 6 mm step down was not taken into account. As for the difference on the x axis, the biggest deviation was in step down 4 mm by 3.9 mm compared to step down 2 mm by 3.6 mm. This shows that the smallest step down experiences a tendency for good geometry profiles.

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