STUDY ON FORMABILITY SIMULATION OF ALUMINUM SHEET 1.5MM THICKNESS

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ABSTRACT

Incremental sheet forming (ISF) technology is a sheet material forming technique where a sheet is formed into the final workpiece by a series of small incremental deformations. Two point incremental forming (TPIF) technology is one of ISF technology. It is suitable in small batches manufacture and having advantages such as easy to change shape, dimension, and etc. with low production time, hight quality, and etc. This study shows deformability of aluminum sheet A1050 H14, 1.5 mm thickness by Abaqus software with TPIF process. According to simulation results, we can put deformability of aluminum sheet A 1050 H14 into practice production.

Keywords: *Design of experiment, CNC, TPIF, finite element method, formability.*

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1. INTRODUCTION

TPIF technology is widely applied in manufacture with advantages such as easy to change shape, dimension, and etc. This technology uses the end of forming tool to deform layer by layer of material sheet until final-shape product with CNC tool path. The material sheet (dimensions of the metal sheet are 400 x 400 mm^2 and 1.5 thickness) is clamped on Jig and fixture system and moving down along guide bars with the end of forming tool (Fig.1). A review of numerical simulation study for TPIF process such as.

In Vietnam, study on the forming angle of aluminum alloy research on the forming angle of aluminum alloy [1]; study on the formability of composite plates [2] and deformability of PVC [3]. The studies were successful in SPIF process [1-8].

The other countries, R. Perez-Santiago et al. [9] investigate force is a more rigorous process parameter for validation of FEM models qualitative trends like thickness distribution and higher forces obtained at higher $\Delta\theta$ are correctly reproduced. Adil Shbeeb Jaber et al. [10] study forming mechanism and multi stages incremental forming. Step size and forming tool radius, on the thickness distribution and strain analyses for three stages in multi, with vertical angle. 2D model of cone shaped part with right forming angle with a wall angle of 60°, thickness (1 mm) of the aluminum alloy (AA1070). ANSYS 11 software is used to carry out the numerical simulation of the multi stage. The results show that, when considering multi-stage incremental sheet forming, the task is even more difficult because the strain and thickness distribution resulting from the first stage will influence the subsequent results. Decreasing in the forming tool radius will increase in the thinning of the wall product due to excessive stretch will occurs, while the incremental step size is not significant effect on the numerical results (thickness, strain) distribution of the product. Finally, the goal to attain a vertical wall angle and equally maintain wall thickness and strain over the wall part is pursued. Mechanical tests, computer programming, geometry and design were required. The simulation results including the thickness and strain distributions over the product walls throughout three stages were concluded.

Overall, numerical simulation studies for the formability of sheet material in TPIF process has not been studied clearly. This paper focuses to simulate on the formability of aluminum sheet A 1050 H14, thickness of 1.5mm at room temperature. A step frustum cone shape with 1° for every step (investigated angle from 65° - 85°) is used to investigate formability of the TPIF process. This investigated shape is a new model in study on the formability by TPIF technology. Spindle speed, depth step, feed rate, and tool diameter are main effect parameters on the formability of TPIF process. The formability of aluminum in TPIF process was predicted by Abaqus software.

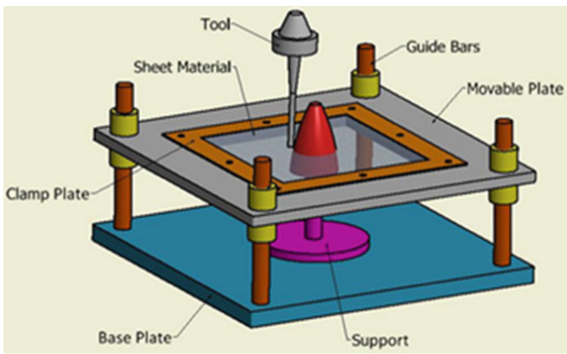

Fig. 1. Fixture system for TPIF process

2. FINITE ELEMENT MODEL OF TPIF PROCESS

The Box-Behnken experiment mode is used 4 factors, 5 center points has identified the relationship of the four technological parameters (Table 1).

2.1. The influence parameters

Table 1. Machining parameters

No	Machining parameters	Unit	Range of values		
			Low level	medium	High level
1	Depth step (z)	mm	0.1	0.8	1.5
2	Feed rate (V_{xy})	mm/minute	300	900	1500
3	Tool diameter (D)	mm	6	12	18
4	Spindle speed (n)	rpm	300	1050	1800

2.2. Building analysis mode

The workpiece is clamped tightly on four side edges, under the workpiece is a support. The real model is modeled (Fig. 1). The metal sheet is fixed four sides, the underside of the metal sheet is contact with the support. The support and the forming tool is defined as absolute rigid. The forming tool moves in the three directions x, y and z (Fig. 2).

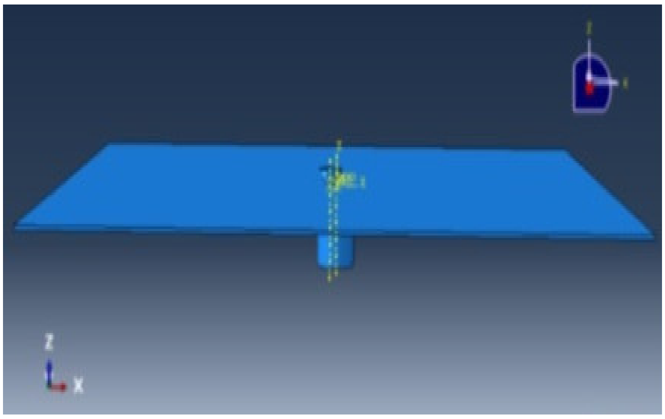

Fig. 2. Simulation model

Create simulation material

Physical properties of A 1050 H14 sheet 1.5mm thickness shown in Table 2. The real stress and strain graph are shown in Fig. 3.

Table 2. Physical properties of A 1050 H14 sheet.

Melting Point	650 C
Density	$2.71 g/cm^3$
Thermal Expansion	$24x10^{-6}K^{-1}$
Thermal conductivity, room temperature	222W/mK
Electrical resistivity, room temperature	$0.0282x10^{-6}\Omega.m$
Poisson's ratio	0.33
Tensile strength	131.74 MPa
Proof Stress	85 Min MPa
Elongation	16%
Elastic Modulus	68.916MPa

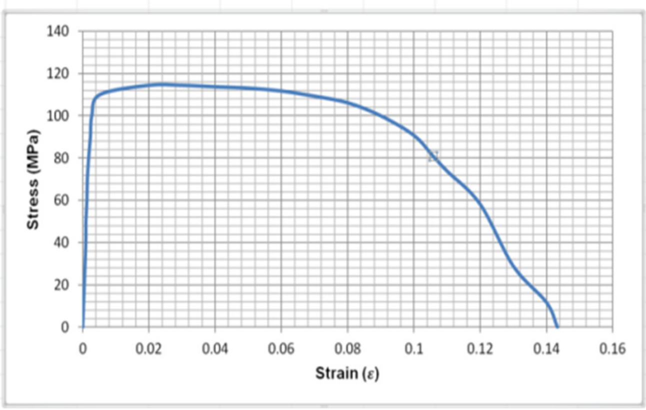

Fig. 3. True stress - strain curves of aluminum sheet A 1050 H14 [12]

Condition of contact

Interaction property between material sheet and the support is tangential behavior. The coefficient of friction between the material sheet and the end of forming tool was chosen to be 0.1 [11].

Meshing

Element type C3D6T, the element size divided is 1.5mm with a mesh, thickness of 5 layers. It does not alter the topology of the mesh but does imply some limitations on the method's ability to maintain a high-quality mesh over maximum strain.

Model for formability investigate

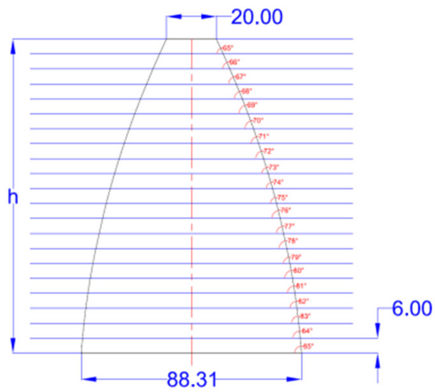

Fig. 4. Step frustum cone shape with 1° for every step

3. RESULTS AND DISCUSSION

According to the DOE experimental matrix table, we select two typical cases to predict using Abaqus software.

3.1. Case 1

Table 3. Machining parameters for case 1

No	Influent parameters	Symbols	Unit	values	Forming angle α (°)
1	Spindle speed	n	rpm	1800	82°
2	Depth step *z*	Δz	mm	0.8	
3	Feed rate	V_{xy}	mm/minute	900	
4	Tool diameter	D	mm	18	

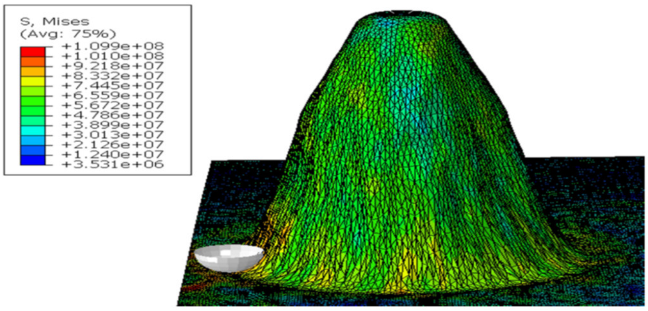

Fig. 5. This is a product after simulated forming.

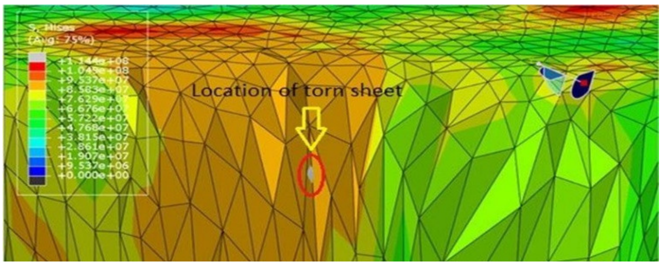

Fig. 6. Location of torn sheet

3.2. Case 2

Table 4. Machining parameters for case 2

No	Influent parameters	Symbols	Unit	values	Forming angle α (⁰)
1	Spindle speed	n	rpm	1050	81⁰
2	Depth step *z*	Δz	mm	0.8	
3	Feed rate	V_{xy}	mm/minute	900	
4	Tool diameter	D	mm	12	

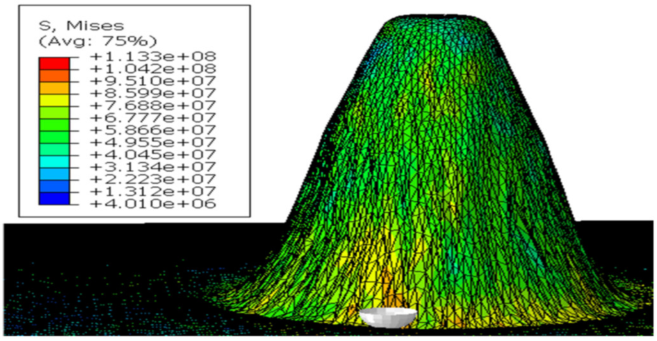

Fig. 7. This is a product after simulated forming

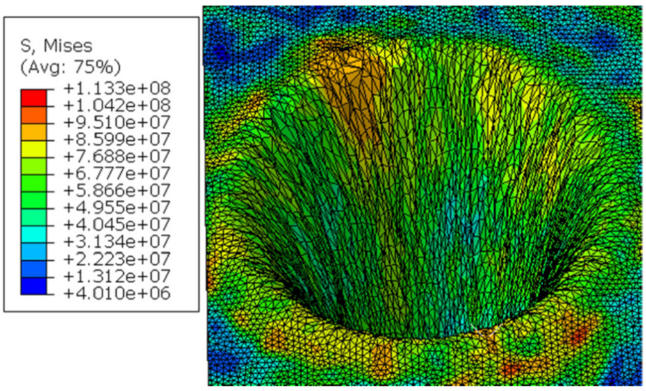

Fig. 8. Location of excessively deformed mesh.

4. CONCLUSIONS

The paper successfully builts a step frustum cone model with increasing investigation range 65° - 85°, each step is one degree to investigate formability of sheet metal.

Predict formability of A1050 H14, 1.5mm thickness with 4 main parameters such as forming depth (Δz), diameter of tool (D), feed rate (V_{xy}), and spindle (n) as Table 5.

Simulated TPIF process.

Table 5. Machining parameters and forming angle

No	Tool diameter (mm)	Depth step z (mm)	Feed rate V_{xy} (mm/minute)	Spindle speed (rpm)	Forming angle α (⁰) simulation
1	18	0.8	900	1800	82
2	12	0.8	900	1050	81

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