3D FINITE ELEMENT SIMULATION STUDY OF MICRO SINGLE POINT INCREMENTAL FORMING

Ramzi Ben Hmida [a] Sebastien Thibaud [a,b] Fabrice Richard [a,c] Pierrick Malécot [a,b]

[a] FEMTO-ST Institute, Department of Applied Mechanics, UMR CNRS 6174, 24 rue de l'Epitaphe, 25000 Besançon, France

[b] ENSMM, 26 rue de l'Epitaphe 25000 Besançon Cedex, France

[c] Université de Franche-Comté, 25000 Besançon Cedex, France

*C A: Ramzi Ben Hmida: ramzi.ben_hmida@univ-fcomte.fr

Keywords: incremental forming, numerical simulation, micro-forming, elastic-plastic material, continuum damage

1. Introduction

The demand of micro-parts is significantly increased due to the trend of product miniaturization in diverse engineering fields. These products can be manufactured by means of many processes. Moreover, microforming is the most cost effective process to fabricate micro metallic parts with high precision in mass production as reported by Geiger et al. [1]. In this context, Micro-single point incremental forming process (micro-SPIF) has been greatly developed over the last few decades. The idea is to locally deform a sheet using a hemispherical end rigid forming tool according to a given tool path often using a CNC machine. The flexibility and the low cost tooling are the main advantages of the subject process. Ben Hmida et al. [2] have demonstrated the possibility of producing microparts using the micro-SPIF process.

The numerical simulations based on the finite element method are very useful for the development of this process particularly to study the effects of process parameters, such as the vertical increment, the tool size and the forming strategies on the thickness and deformation distributions, the final shape, and formability.

2. Experimental study

The experimental device is illustrated in Fig. 1 (a). It is composed of a fix die support, a modular die, a fix blank holder clamped with the die by screws and the forming tool (end ball tool). The lubrication of the sheet/tool interface (water/oil mixture) is used to reduce friction and improve the sheet formability. The forming process is performed by using a CNC machine tool and the forming forces are acquired by a piezoelectric dynamometer. In this study, a pyramidal shape of the finished part (Fig. 1 (b)) is considered and a forming tool with a radius of 1 mm was used. It is rotated by a constant speed rate of 1000 rpm and moved with a constant feed rate of 500 mm/min. Here, a spiral tool path is used, as shown in Fig. 1 (b).

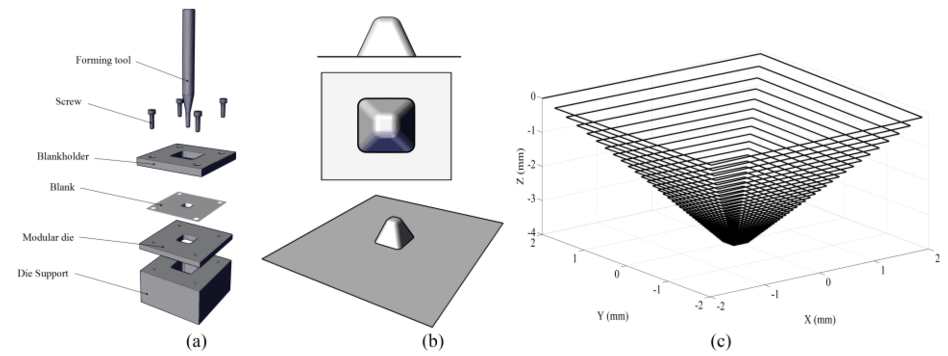

Figure 1: (a) Experimental device, (b) Pyramidal part shape, (c) Tool path.

3. Numerical study

To simulate the process of micro-incremental sheet metal forming, a finite element model was developed using the LS-DYNA® software (dynamic explicit). Fully integrated eight nodes solid elements are used to mesh the blank and to take into account the shear and bending effects. Three elements in thickness are thus considered for predicting forming behavior of sheet metal. Each tool (forming tool, die and blank holder) is meshed with rigid shell elements. During the simulation, the boundaries of the blank are considered to be clamped. This model is completely detailed and validated in the study proposed by Thibaud et al.[3]. Coulomb tool/sheet frictional constant behavior is adapted, with a friction coefficient equal to 0.2. The damaged elastic-plastic isotropic model in the isothermal ductile case is described in the context of the thermodynamics of irreversible processes with internal state variables. The continuum damage mechanics concepts developed by Lemaitre et Desmorat [4] are considered. The material parameters of the behaviour law are identified by inverse analysis using the process itself [5].

4. Results

To validate the numerical model, comparisons between experiments and simulations were considered in terms of geometry and effort forming.

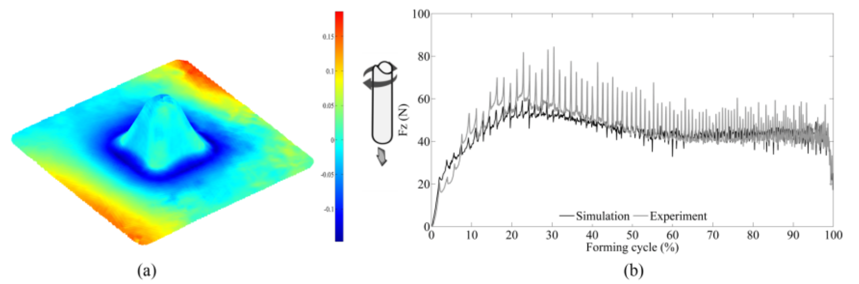

Figure 2: (a) 3D geometrical comparison, (b) Axial forming forces comparison.

The obtained parts were analyzed by reverse engineering technique and the experimental geometry was compared with the numerical one, as shown in (Fig. 2 (a)). A good agreement between the numerical prediction and the obtained geometry was pointed out. Moreover, the axial forming forces (Fig. 2 (b)) are compared with experiments. The results show a good correlation between experiment and simulation forming forces; especially variations and levels are closed.

5. Bibliography

[1] M. Geiger, M. Kleiner, R. Eckstein, N. Tiesler, et U. Engel, « Microforming », *CIRP Ann. - Manuf. Technol.*, vol. 50, nº 2, p. 445-462, 2001.

[2] R. Ben Hmida, S. Thibaud, A. Gilbin, et F. Richard, « Influence of the initial grain size in single point incremental forming process for thin sheets metal and microparts: Experimental investigations », *Mater. Des.*, vol. 45, p. 155-165, mars 2013.

[3] S. Thibaud, R. Ben Hmida, F. Richard, et P. Malécot, « A fully parametric toolbox for the simulation of single point incremental sheet forming process: Numerical feasibility and experimental validation », *Simul. Model. Pract. Theory*, vol. 29, p. 32-43, déc. 2012.

[4] J. Lemaitre et R. Desmorat, *Engineering Damage Mechanics: Ductile, Creep, Fatigue and Brittle Failures*. Springer, 2005.

[5] F. Richard, R. Ben Hmida, S. Thibaud, P. Malécot et C. Radu « Parameter identification in damage elastic-plastic by instrumented micro-single point incremental forming process in micro length scale» In review.