VIII International Conference on Computational Plasticity
COMPLAS VIII
E. Oñate and D. R. J. Owen (Eds)

THREE-DIMENSIONAL FE SIMULATION OF SINGLE POINT INCREMENTAL FORMING: EXPERIMENTAL EVIDENCES AND PROCESS DESIGN IMPROVING

G. Ambrogio[*], L. Filice[*], F. Gagliardi[*] and F. Micari[†]

[*]Department of Mechanical Engineering
University of Calabria, Arcavacata of Rende, 87036 Cosenza, Italy
e-mail: l.filice@unical.it, web page: www.unical.it

[†] Department of Manufacturing and Management Engineering
University of Palermo, Viale delle Scienze, 90128 Palermo, Italy
e-mail: micari@dtom.unipa.it, web page: www.unipa.it

Key words: Sheet Metal Forming, Incremental Forming, Numerical Simulation.

Summary. *Besides the presence of low accuracy, which limited up to now its industrial application, single point incremental forming exalts the advantages of Incremental Forming since no dies are strictly necessary. At the same time, the numerical simulation may supplied technical support to the designers only if the simulation time is comparable with the trial and error tests. With this aim, a FE model, derived by the application of a explicit approach, has been developed and a suitable application for the process design has been defined in the present paper.*

1 INTRODUCTION

Single Point Incremental Forming is an innovative process which allows to produce complex sheet components by CNC movement of a simple tool, with or without the combined use of simple dies[1]. Blank material is completely clamped by a simple frame and a hemispherical punch is used as deforming tool (Figure 1). In this contest, Single Point Incremental Forming may constitute a suitable industrial alternative, especially if one or few parts have to be produced, since no expensive dies are required. In the mean time, process mechanics is mainly characterised by stretching condition[2]: therefore a relevant sheet thinning occurs, which penalizes process suitability. More in detail, sheet thinning in the deformed zone may be approximated through the well known sine law, which relates the final thickness to the slope of the formed surface[3]. Actually some relevant deviations from this simple model are highlighted carrying out simple SPIF experiments.

In this paper, the above issues were accurately investigated, carrying out both experimental and numerical tests, with the aim to develop a suitable SPIF design tool. It's quite evident that a relevant research effort has to be spent to lead Incremental Forming among the mature manufacturing processes. Unfortunately, up to now, one of the main research problem is due to the very high computational time required using the well reliable implicit FE codes[4,5]. Simulation time of several days is quite normal, resulting in very expensive research tasks. A revolution in this field is represented by the application of numerical codes based on an explicit formulation, which demonstrated their capabilities for other sheet metal forming applications[6]. In the research here addressed, an effective simulation set-up was developed which permitted to reduce the simulation time of a standard process to about 2 hours, using Dynaform® explicit code on a high-performance PC.

2 EXPERIMENTAL AND NUMERICAL MEASURES

Different process configurations were investigated, both by numerical and experimental approaches, taking into account AA1050-O Aluminium Alloy sheets (1mm thick). More in detail, two different shapes were considered, namely truncated cones and pyramids. Sheet thinning at the end of the process was measured by means of a CMM Coord 3 system (Figure 1); a good agreement between the numerical predictions and the experimental results was found out (Figures 2-3), thus confirming the potentiality of the FEM tool.

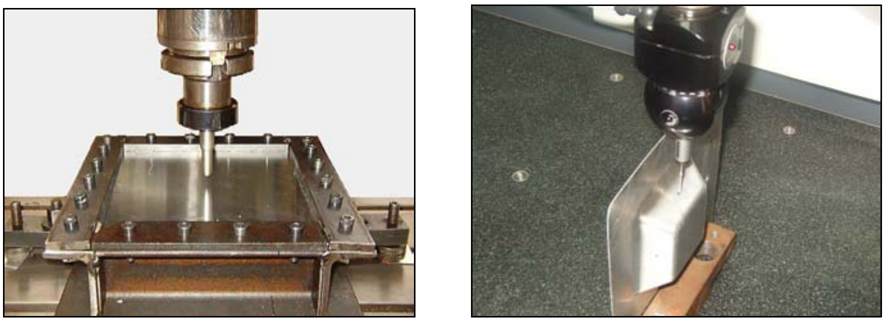


Figure 1: The experimental equipment

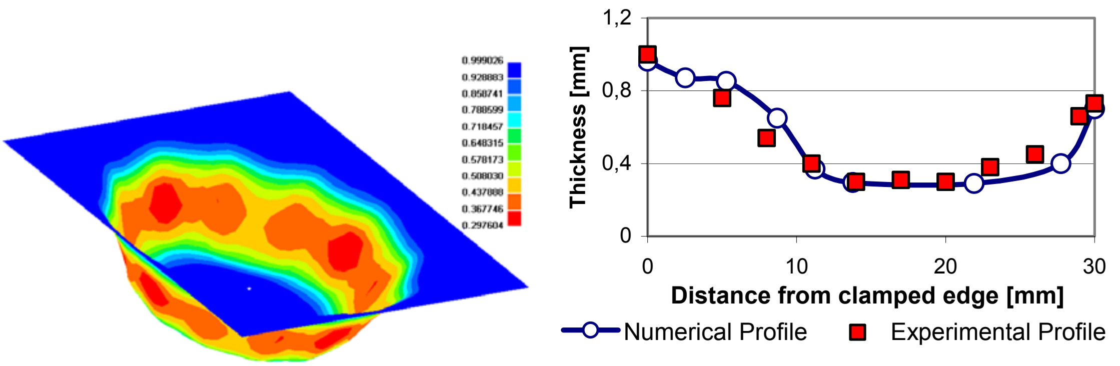


Figure 2: Numerical prediction and comparison between numerical and experimental thickness distribution (truncated cone)

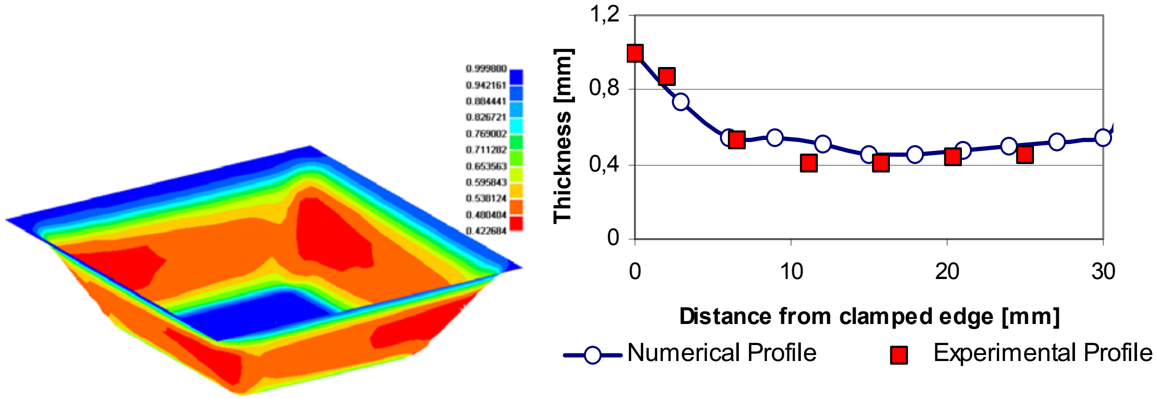


Figure 2: Numerical prediction and comparison between numerical and experimental thickness distribution (truncated pyramid)

3 PROCESS DESIGN OF A CYLINDRICAL CUP

Once the capability to predict sheet thinning was assessed, the further step was to verify the possibility to use the numerical model as design tool. It's worth outlining that one major research issue concerning Incremental Forming is the possibility to produce almost vertical walls, for instance cylindrical cups. Actually one-step SPIF does not permit to pursue such task, but a pre-forming step is necessary, followed by back-drawing Incremental Forming[7]. The cup geometry reported in the next Figure 4 was taken into account; the numerical model was utilized in order to design the most effective SPIF sequence allowing to avoid excessive thinning and failure of the material. As far as the latter issue is concerned the calculated strains were compared with the material FLD_0, i.e. the limiting strain at fracture in plane strain conditions.

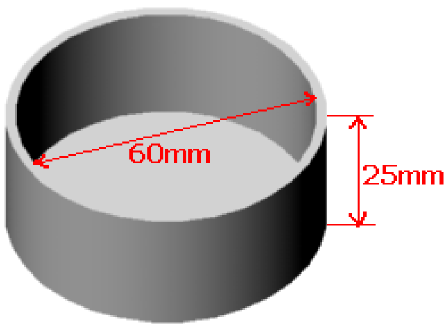
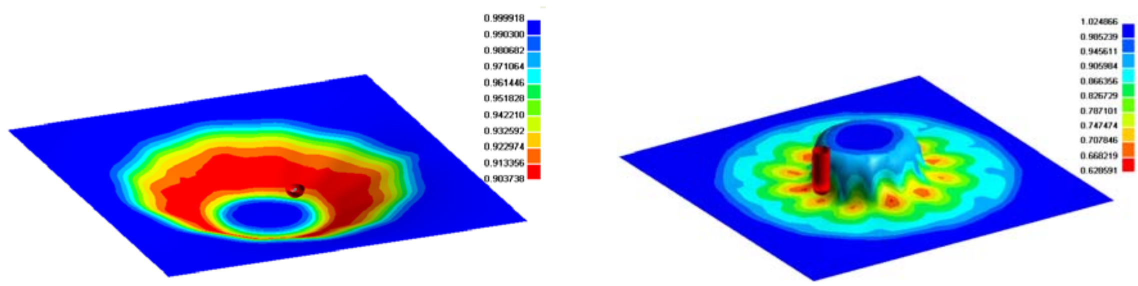


Figure 4: Sketch of the desired cup

Of course thinning strongly depends on the cup radius and height and, also, on the initial blank radius. The latter parameter represented the most important process parameter: when unsafe process conditions were predicted by the numerical code, the blank radius was increased to achieve a safer design. Figure 5 reports the simulated incremental forming sequence, and highlights the calculated thickness. As it can be observed, the minimum thickness value is equal to 0.62 mm, which results compatible with the utilised material. In this way, the FEM model suggests that the proposed incremental forming sequence safely permits to produce the desired cup.



(a) (b)

Figure 5: Cup manufacturing after pre-forming (a) and back-drawing incremental forming (b)

Obviously, the numerical result has to be confirmed by an experimental test, as a consequent step of the research; anyway, these former results are very impressive, taking into account that, due to the cited numerical problems, up to now the main investigations on Incremental Forming were purely experimental activities, surely money and time consuming.

REFERENCES

[1] M. Bambach, G. Hirt, S. Junk, “Modelling and experimental Evaluation of the Incremental CNC sheet metal forming process”, *7th International Conference on Computational Plasticity*, (2003).

[2] G. Ambrogio, L. Filice, L. Fratini, F. Micari, “Some relevant correlations between process parameters and process performance in incremental forming of metal sheets”, Proceedings of the 6th Esaform Conference on Material Forming, 175-178 (2003).

[3] K. Kitazawa, A. Nakajima, “Cylindrical incremental drawing of sheet metals by CNC incremental forming process”, *Proc. of the 6th ICTP Conference*, 1495-1500 (1999).

[4] G. Ambrogio, L. Filice, L. Fratini, F. Micari, “Process mechanics analysis in Single Point Incremental Forming”, *Proc. of the 8th International Conference on Numerical Methods in Industrial Forming Processes (NUMIFORM)*, 922-927 (2004).

[5] G. Hirt, S. Junk, N. Wituski, “Incremental sheet forming: quality evaluation and process simulation”, *Proceeding of the 7th ICTP Conference*, 925-930 (2002).

[6] J. Rojek, O.C: Zienkiewicz, E. Onate, E. Postek, “Advances in FE explicit formulation for simulation of metalforming processes”, *International Journal of Materials Processing Technology*, vol. 119 Issue 1-3, 41-47 (2001).

[7] G. Hirt, S. Junk, M. Bambach, I. Chouvalova, “Process limits and material behaviour in Incremental Sheet Forming with CNC-Tools”, *THERMEC 2003, International Conference on Processing & Manufacturing of Advanced Materials – Processing, Fabrication, Properties, Applications*, (2003).

[8] L. Fratini, G. Ambrogio, R. Di Lorenzo, L. Filice, F. Micari, “Influence of Mechanical Properties of the Sheet Material on Formability in Single Point Incremental Forming”, *Annals of the CIRP*, Vol. 53/1/2004, 207-210, (2004).