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Review On Single Point Micro Incremental Forming On Thin Foils

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Abstract- Single-point incremental sheet forming (SPISF) is a die-less forming process with advantages of high-flexibility, low-cost and short lead time. Medical applications such as implant components, surgical tool and tooth caring accessories etc. make use of micro components in large scale. Out of the recent technological innovations made in micro manufacturing Micro Forming plays a major role. The process in which numerically controlled tool motion locally deforms the metal and results in higher formability than the conventional stamping process is Micro Incremental sheet forming (ISF). To study the deformation mechanisms in micro SPISF process numerical and experimental studies have been made. Single Point Micro Incremental Forming of Aluminum, Copper and Mild Steel sheets of different thicknesses were tested for formability. The standard geometry used for measuring the maximum forming angle that could be achieved in micro-SPISF process is a truncated pyramid with variable half-apex angle. The influence of process parameters on forming behavior was studied and forming angle has direct link with material formability.

I. INTRODUCTION

Micro Incremental sheet forming (ISF) which is a flexible manufacturing process is capable of producing customized components in short lead time. Many studies have been done to investigate the deformation mechanism of ISF in the macro scale. The production of metallic parts by forming with at least two part dimensions in the sub millimeter range is called Micro forming. State-of-the-art for micro manufacturing is miniaturization of products. Research on this area over the recent decade has been moved from “process and technology focus” to “market/product”-driven activities.

II. LITERATURE REVIEW

Many studies have been done to investigate the deformation mechanism of ISF in the macro scale. [1] Toshiyuki et al performed incremental forming of aluminium foils using CNC milling machine. When water was used as lubricant, hydrodynamic lubrication between tool and foil reduced the forming forces and promoted local plastics deformation. An array of dots 0.1mm in diameter, miniature car, miniature letters and miniature pyramids were formed on thin sheets. [2] Ben Hmida et al conducted tests of FPG copper foils with different grain sizes. The yield stress, tensile strength and ductility decrease with the decreasing ratio of specimen size ob=ver grain size. Formability for the incremental forming process detoriates as t/d ratio decreases. There is a decrease in the level of forming forces with respect to the grain size. [4] Saotome and Okamato developed a specialized device to manufacture micro-structures in a scanning electron microscope to demonstrate the feasibility of scaling down SPISF. The micro SPISF was initially demonstrated by Obikawa [1]. They converted a conventional CNC machine into a micro SPISF system to study the formability of aluminum foils. [5] GmelaHapsari et al validated the ductile damage model and its associated material parameters by comparing the results of simulation different micro incremental forming processes to experiments. [7] Tegan presented that the material thickness should also be a consideration in optimization of tool diameter, in order to achieve maximum formability. Feed rate and spindle speed both be optimized depending on the material type. Spindle speed is a major factor in the heat generated from friction. [8] Gupta et al observed heat generation in single point incremental forming. The temperature at the tool-sheet interface can be increased by increasing tool rotation speed while maintaining high feed rates. Flat tool contacts at two distinguishable points over the sheet creating two heat generation zones. Heat loses from the system through the backing plate to the rig. The increase in temperature energizes the slip planes to carry out dislocation movement to accommodate plastic deformation. Thus it reduces the forming forces while increasing plasticity. [9] Malwad et al concluded that the biggest deviation could be found by the variation of wall angle of forming. Greater formability and depth can be achieved for wall angle less than 750. As the wall angle increases stretching plays an important role in deformation than shearing. Tool size affects both formability and the surface finish of the part. The crack occurs mostly at the corners due to Bi-axial stretching. [10] Suresh Kurra et al investigated surface roughness of incrementally formed parts with EDD steel under different forming conditions. Predictive models are developed using ANN, SVR and GP. Adequacy of model is tested using hypothesis tests and performance is evaluated using R2 value. The models developed using ANN and SVR are performing better than GP. SVR exhibited better performance in predicting Ra and Rz .[11] Kim and Park showed the deformation mechanism of the process was the combination of stretching and spinning. Effect of process parameters such as tool type, tool size, feed rate, friction at the interface between tool and sheet, plane, anisotropy of sheet on the formability was also investigated.

III. MICRO MANUFACTURING METHODS AND PROCESSES

The trend for micro-manufacturing at the present time is more focused on miniaturizing or down-scaling both conventional and non-conventional methods to produce micro-products. According to the way in which components/products are to be made, general manufacturing processes can also be classified into subtractive, additive, forming, joining and hybrid processes. The classification is equally applicable to micro manufacturing. Typical manufacturing methods against the way of producing components/products are show in Table 1.

Subtractive Processes	Micro-Mechanical Cutting (milling, turning, grinding, polishing, etc.) Micro-EDM Laser Beam Machining Electron Beam Machining Photo-chemical-machining
Additive Processes	Surface coating (CVD, PVD) Direct writing (inkjet, laser-guided) Micro-casting Micro-injection moulding Sintering Photo-electro-forming Chemical deposition Polymer deposition Stereo lithography
Deforming Processes	Micro-forming (stamping, extrusion, forging, bending, deep drawing, incremental forming, super plastic forming, hydro-forming, etc.) Hot embossing Micro / Nano-imprinting
Joining processes	Micro-Mechanical-Assembly Laser-welding Resistance, Laser, Vacuum Soldering Bonding Gluing
Hybrid Processes	Micro-Laser-ECM LIGA and LIGA combined with Laser-machining Micro-EDM and Laser assembly Shape Deposition and Laser machining Laser-assisted-micro-forming Micro assembly injection moulding Combined micro-machining and casting

Table.1

IV. EXPERIMENTAL STUDY

[5] The selected material is copper alloy band with initial thickness of 130μm. To conduct the experiments a dedicated apparatus is used. It is composed of a fixed die support, a modular die, a fixed blank holder clamped with the dies by screws and the hemispherical forming tool. The forming process is done on a CNC machine (3-axis micro milling machine). The measurement of the forming forces on 3 direction of CNC axis and the torque on the z-axis is done by a 4-axis dynamometer (Fig. 1.). A pyramidal shape is used to further investigate the influence of miniaturization (Fig. 2.).

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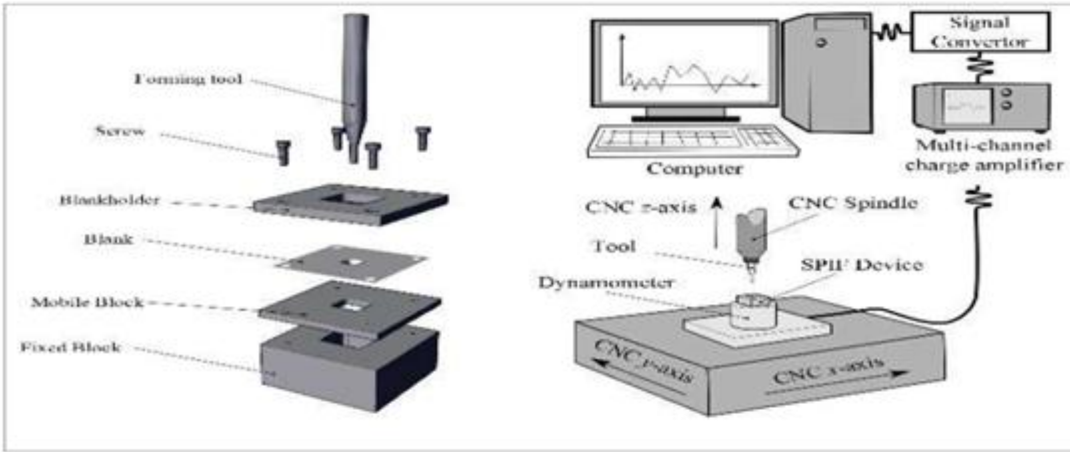

Figure1. Apparatus and supporting equipment.

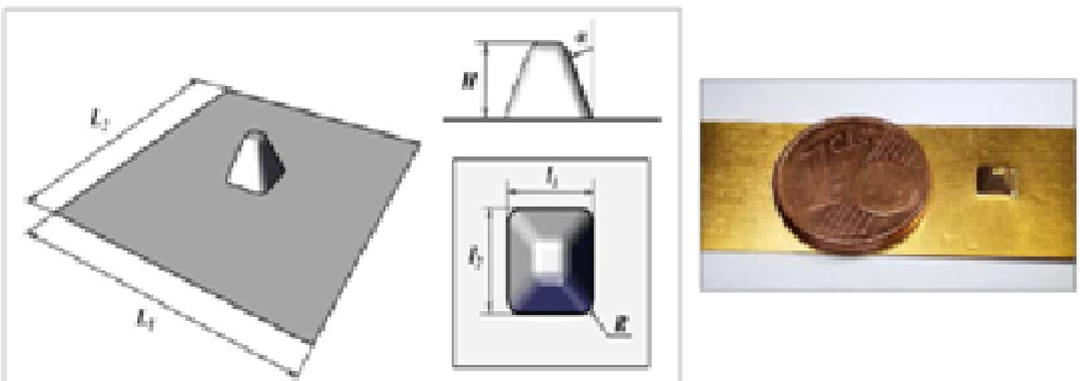

Figure2. (a) Geometry of pyramid (b) Sample of forming pyramid by ISF

V. NUMERICAL SOLUTIONS

[5] By using a dedicated toolbox programmed in MATLAB® language, the parametric model (mesh, boundary, loading and initial conditions, material behavior) is created. The keyword file produced as the result of this toolbox then used to run the simulations with LS-DYNA software. The blank is meshed with solid elements with 120 elements in the length and 8 nodes fully integrated to get as much information from the thickness. Forming tool, die and blank holder are meshed with rigid shell elements (quad elements). Boundary condition applied for the blank is clamp to ensure null degrees of freedom of each nodes on the blank boundary.

VI. MICRO MANUFACTURING AND KEY ISSUES

The design of micro-products for micro-manufacturing needs to address production issues extensively to be able to succeed compared to the situation with prototype-products based on micro-technologies. The main goal for the design of micro-manufacturing should be the high-volume production of micro-components. Both functional requirements and micro-manufacturing related factors need to be considered while designing these products. This is because manufacturing these products renders more significant challenges, compared to those for the manufacture of macro-products. Issues related to micro manufacturing have been addressed intensively by many researchers.

VII. CONCLUSION

Micro-manufacturing has received good attention globally in terms of its manufacturing methods/processes. Micro-forming is one of the most popular micro-manufacturing process. Many efforts have been focused on microforming especially on the micro-stamping process as the process itself contributes to numerous products, especially in its conventional process. Almost all day to day products are made by this process. Although there were efforts made to realize micro stamping for industrial application, the technology itself was seen as being insufficiently mature. Much development work needed to be done, specifically to develop a fully-automated high-volume production micro-stamping machine, which is reliable and at all times ready for operation in terms of it processes, tooling, and material-handling to ensure the successful production of micro-products.

VIII. REFERENCE

[1] Toshiyuki Obhikawa, ShunsukeSatou, Tomomi Hakutani, Dielessincrementalmicro-forming of miniature shell objects of aluminium foils, International Journal of Machine Tools and Manufacture 49 (2009) 906-915.
[2] R. Ben Hmida, S. Thibaud, A. Gilbin, F. Richard, Influence of the initial grain size in single point incremental forming process for thin sheets metal and microparts: Experimental investigations, Materials and Design 45 (2013) 155-165.
[3] F. Vollertsen, H. Schulze Niehoff, Z. Hu, State of the art in microforming, International Journal of Machine Tools and Manufacture 46 (2006) 1172-1179.
[4] YasunoriSaotome, Takeshi Okamoto, An in-situ incremental microforming system for three-dimensional shell structures of foil materials, Journal of Material Processing Technology 113 (2001) 636-640.
[5] GamelaHapsari, Ramzi Ben Hmida, Fabrice Richard, Sebastien Thibaud, PierrickMalecot, A Procedure for Ductile Damage Parameters Identification by Micro Incremental Sheet Forming, Procedia Engineering 183 (2017) 125-130.
[6] Song X, Zhang J, Zhai W, Taureza M, Castagne S, Danno A, Numerical and Experimental Study of Micro Single Point Incremental Forming Process, International Conference on the Technology of Plasticity, ICTP 2017, 17-22 September 2017, Cambridge, United Kingdom.
[7] Tegan McAnulty, Jack Jeswiet, Mathew Doolan, Formability in single point incremental forming: A comparative analysis of the state of art, CIRP Journal of Manufacturing Science and Technology 16 (2017) 43-54.
[8] P. Gupta, J. Jeswiet, Observations on heat generated in single point incremental forming, Procedia Engineering 183 (2017) 161-167.
[9] D. S. Malwad, Dr. V. M. Nandedkar, Deformation Mechanism Analysis of Single Point Incremental Sheet Metal Forming, Procedia Materials Science 6 (2014) 1505-1510.
[10] Suresh Kurra, NasihHifzur Rahman, Srinivasa Prakash Regalla, Amit Kumar Gupta, Modeling and optimization of surface roughness in single pont incremental forming process, Journal of Materials Research and Technology 2015; 4(3): 304-313.
[11] Y.H. Kim, J.J. Park, Effect of process parameters on formability in incremental forming of sheet metal, Journal of Materials Processing Technology 130-131 (2002) 42-46.