ISSN : 2455-9679
Impact Factor : 2.865

ijrtsm

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"THE MECHANISM OF INCREMENTAL SHEET FORMING"

Rajeev Gupta [1], Abhishek Sharma [2], Nitin Kumar Rathi [3]
[1,2]Assistant Professor, Dept. of Mechanical Engineering, Acropolis institute of technology and research, Indore
[3]Associate Professor, Dept. of Mechanical Engineering, Acropolis institute of technology and research, Indore

ABSTRACT

Incremental sheet forming (ISF) is a flexible process where an indenter moves over the surface of a sheet of metal to form a 3D shell incrementally (with the help of CNC Milling) by a progression of localized deformation (stresses greater than yield stress). Despite extensive research into the process, the deformation mechanics is not fully understood. The mechanics of ISF of sheet metals is researched. Through-thickness deformation and strains of copper/Aluminum plates are measured for single-point incremental forming (SPIF) and two-point incremental forming (TPIF). It is shown that the deformation mechanisms of SPIF and TPIF are shear parallel to the tool direction, with both shear and stretching perpendicular to the tool direction. Tool forces are measured and compared throughout the two processes. Tool forces follow similar trends to strains, suggesting that shear parallel to the tool direction is a result of friction between the tool and work piece.

Keyword: *SPIF, TPIF, Incremental deformation.*

I. INTRODUCTION

Incremental sheet forming (ISF) is an umbrella term describing a diverse range of processes in which a sheet of metal is formed into a 3D shell by a simple tool causing a progression of localized Permanent deformation. The most ancient forms of metal forming processes were manual incremental forming processes, including spinning, where a craftsman forms a rotating work piece over a mandrel, and reposes or chasing, in which impressions are formed on a sheet of metal by hammering or pressing against a sack filled with sand.

Despite its ancient roots, it is only in the last two decades that the usage and capabilities of ISF have grown significantly. This can be attributed to two main factors. Firstly, advances in manufacturing technology, particularly the development of computer numerically controlled (CNC) machinery, has enabled what is traditionally a skilled craft to be carried out with some level of automation. Secondly, a growing interest in customization has brought about a motivation for developing forming processes which do not require specialized tooling. Tooling can be prohibitively expensive when considering small batch sizes or one-offs.

Asymmetric incremental sheet forming. In this process a computer numerically controlled (CNC) indenter moves over the surface of a sheet of metal along an asymmetric path, usually of contours or a spiral of descending depth, defining the form of the product. Hence a diverse range of asymmetric products can be formed without specialized tooling by moving the tool along an appropriately designed path. The phrase 'incremental sheet forming' has therefore recently become most strongly associated with asymmetric CNC incremental sheet forming processes, and shall take this meaning throughout the rest of this thesis. The most basic form of asymmetric ISF is single-point incremental forming

ISSN : 2455-9679
Impact Factor : 2.865

(SPIF) as show in Fig. 1, where a sheet of metal is clamped rigidly around its edges and formed on one surface by a single indenter. This can be compared to a conventional deep- drawing process in which a blank holder allows a sheet of metal to be drawn between a male and female die set which define the complete shape of the product, as illustrated in Fig.1.

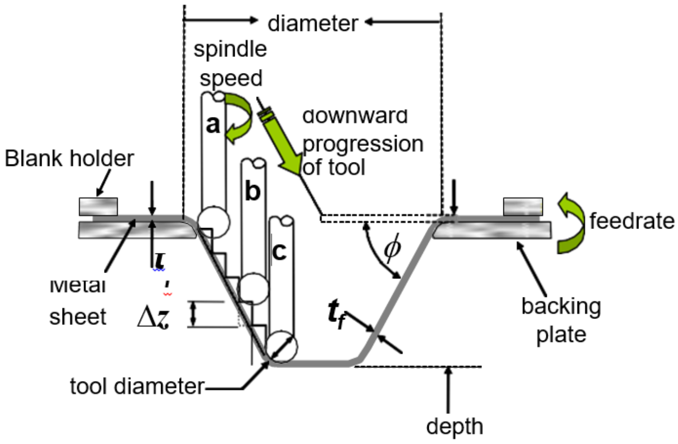

Fig 1: SPIF terminology as seen in deformed part

II. Geometry and Geometric Accuracy

Measurements of geometry and geometric accuracy of sheets formed by ISF have been carried out both during and after forming, where the sheet may be measured whilst still mounted in the machine. Three principal methods have been used to measure geometry and geometric accuracy in ISF: co-ordinate measuring machines (CMMs); laser scanners; and 3D stereovision systems. Co-ordinate measuring machines provide a simple means of taking point-by-point measurements of the geometry of sheets formed by ISF after removal from the machine and have the advantage of being available in most engineering workshops. Meier et al [1] used a CMM to measure various frustums of pyramids and Hirt et al [2] used one to measure cross-sections for comparison to a FE model. However, this technique is time consuming, labor intensive, does not allow for measurement of the sheet whilst in the machine (i.e. before spring back due to removal of the clamp) and can potentially lead to errors if the stylus is manually positioned. Laser scanners or stereovision systems are more suitable for rapid measurement of full 3D surfaces and can be used whilst the sheet is still in the machine. Laser scanners measure the geometry of a sheet by scanning across it in a line. Duflou et al [3] used a laser scanner to measure a formed sheet to an accuracy of ±15μm and Ambrogio et al [4] used a Minolta Vivid 300 laser scanner to accurately measure formed sheets, in both cases after removal from the machine. Sheets measured by a laser scanner have to be prepared with a non-reflective surface such as varnish to avoid high reflectance. A stereovision system offers the advantage over a laser scanner of imaging of the entire surface simultaneously; a scan is not required. Strains are calculated by comparing a pattern on the surface in the current position to the pattern at some earlier time measured by two calibrated CCD cameras. Hirt et al [5] have used an ARAMIS stereovision system and Watzeels et al [6] have used a LIMESS system. Although laser scanners and stereovision systems offer rapid and accurate 3D measurements, a problem that can be encountered is that the sheet surface can be partly obscured whilst it is mounted in the machine, and hence the full surface may not be measurable. In addition, painted-on patterns required for the optical systems can become detached during forming and 3D images can take several seconds to analyze. Overall, 3D stereovision systems offer the fastest measurement of the deformation of the sheet surface, but their usage is limited primarily due to expense and availability.

III. Strains

Three methods have been applied for measurement of strains on the surface of the sheet in ISF: strain gauges; measurement of grids applied to the surface; and stereovision systems. Strain gauges can be used to measure the development of strains at discrete points on the sheet surface throughout the forming process, as used by Kitazawa [7].

ISSN : 2455-9679
Impact Factor : 2.865

However, these have the limitations of being difficult to attach, measuring the strain over a finite area at discrete points only and failing under high strains. An alternative and more popular technique for measurement of strains across the full surface of the sheet after forming is by comparing the size of a grid of circles applied to the surface before forming to the size after forming. The grid can be applied easily using various techniques: Kitazawa [7] used a photographic technique; Shim and Park [8] used electro-chemical etching; Kim and Park [9] manually scribed a grid of squares onto the surface; Filice et al [10] impressed the grid onto the sheet surface and Jeswiet et al [11] used silk-screen printing. For all of the above techniques, the grid pattern must be applied to the surface that is not contacted by the tool to avoid damage. Jeswiet et al [11] have suggested that using etching to apply the grid can reduce the forming limits by causing stress concentrations, therefore printing techniques may be preferable. The major and minor (maximum and minimum) surface strains have been calculated by measuring the major and minor diameters of the distorted ellipses of the grid after forming using either a transparent measuring string or a tool maker's microscope (Kitazawa [8]). A limitation of the grid-based technique using circles is that the strain path is not known. Alternatively, an optical system as described above for measuring displacement can provide a rapid calculation of strains across the surface of the sheet throughout the process. Grid-based techniques are currently the most commonly used for measurement of surface strains in ISF because of their simplicity, low cost and applicability across the whole surface. However, as for measurement of geometry, optical systems offer the fastest analysis of strains but are an expensive option.

IV. TOOL FORCE

Three approaches have been used for measuring tool force in ISF: measurement of reaction forces on the work piece support with a force dynamometer; measurement of forces on the tool post using strain gauges; and measurement of reaction forces on the work piece support with loadcells. Duflou et al [12] used a Kistler 9265B six- component table force dynamometer which showed good repeatability to measure reactions on the workpiece support. Bologa et al [13] used a force dynamometric table to measure forces on two axes. A limitation of the force dynamometer is that it has not yet been used to measure tool force simultaneously with tool position, and hence it has not been possible to resolve the tool force components relative to the instantaneous direction of the tool and instead only the tool forces in a fixed co-ordinate set are known. Alternatively, tool force has been measured by strain gauges on the tool post by Jeswiet et al [14]. This method has not subsequently been widely used because it has the disadvantage of poor accuracy due to horizontal force components being calculated from bending moments with a small bending arm. Overcoming these limitations, the ISF machine at Cambridge University is the only specialized rig to have a built-in system which allows simultaneous measurement of tool force with tool position. Allwood et al [18] mounted the work piece frame on six loadcells to enable real-time force measurement on three axes.

V. THICKNESS AFTER FORMING AND SURFACE ROUGHNESS

Rapid and automatic measurement of sheet thickness in ISF is difficult because points need to be measured accurately on opposing surfaces, where usually only one side is accessible to scanners or CMMs. The thickness at discrete points across a cut cross- section can therefore be manually measured using a micrometer after cutting the sheet, as used by Bambach et al [19]. Alternatively, a CMM can be used to measure the positions of points on opposite sides of the sheet and hence the sheet thickness can be calculated, as used by Ambrogio et al [20]. Surface roughness has been measured accurately under a range of process conditions by Hagan et al [21] using white light interferometry.

VI. THE MECHANICS OF INCREMENTAL FORMING OF SHEET METALS

Despite extensive research in ISF over the last decade, the deformation mechanics is not fully understood and has never been experimentally verified through the thickness of the sheet. An understanding of the deformation mechanism is important to allow accurate numerical models to be developed for tool path design and process control, and to develop an understanding of the increased forming limits observed in ISF in comparison to pressing. Research on the deformation mechanics of ISF has focused on measurement of the strains and displacements of the surfaces of sheets or FE predictions of strains through the thickness. However, experimental measurement of the full through- thickness deformation, which would serve to validate the FE models and give further insight than surface measurements, has not been carried out. The aim of this section is therefore to provide the first experimental measurements of deformation

ISSN : 2455-9679
Impact Factor : 2.865

through the thickness of plates formed by the two most common forms of ISF: SPIF and TPIF against a positive die support. A comparison will also be made to pressing with the aim of distinguishing the key differences which may account for the observed increased forming limits in ISF. Overall, three significant results can be drawn from the above observations for the plate formed : (1) in both SPIF and TPIF the deformation is a combination of stretching and shear that increases on successive laps, with the greatest strain component being shear in the tool direction; (2) shear occurs perpendicular to the tool direction in both SPIF and TPIF, which is more significant in SPIF resulting in a piling up of the material at the center of the plate; (3) the deformation mechanism is inherently different for SPIF and TPIF, and therefore the two processes should be distinguished in future discussions of their deformation mechanics. The observations of the tool force measurements for the C101 plate formed into a truncated cone can be summarized as two principal results: all components of tool force increase on successive laps in both TPIF and SPIF, which is an indication of increasing work and is consistent with the measurements of increasing strains; tool forces are greater for SPIF than TPIF, which is also consistent with the measurements of strains for the two processes.

REFERENCES

1. Meier, H., Dewald, O. and Zhang, J., 2005. A new robot-based sheet metal forming process. In: SheMet '05 International Conference on Sheet Metal. Erlangen, Germany. pp. 465-470.
2. Hirt, G., Bambach, M., Junk, S. and Chouvalova, I., 2003. FEM modelling and optimisation of geometric accuracy in incremental CNC sheet forming, Developments in Equipment Based Accuracy. In: CIRP international conference on accuracy in forming technology (ICAFT/10). Chemnitz. pp. 293-304.
3. Duflou, J., Lauwers, B., Verbert, J., Tunckol, Y. and De Baerdemaeker, H., 2005. Achievable accuracy in single point incremental forming: Case studies. In: 8th ESAFORM Conference. Cluj-Napoca, Romania. Vol. II: pp. 675-678.
4. Ambrogio, G., Costantino, I., DeNapoli, L., Filice, L., Fratini, L. and Muzzupappa, M., 2004. Influence of some relevant parameters on the dimensional accuracy in incremental forming: a numerical and experimental investigation. Journal of Materials Processing Technology. 153-154: pp. 501- 507.
5. Hirt, G., Bambach, M., Junk, S. and Chouvalova, I., 2003. FEM modelling and optimisation of geometric accuracy in incremental CNC sheet forming, Developments in Equipment Based Accuracy. In: CIRP international conference on accuracy in forming technology (ICAFT/10). Chemnitz. pp. 293-304.
6. Watzeels, K., Tunckol, Y., Henrard, C., Gu, J., Sol, H., Duflou, J. and Habraken, A.M., 2005. Experimental validation of the finite element simulation of the first stroke in single point incremental forming. In: 8th ESAFORM Conference. Cluj- Napoca, Romania. Vol. II: pp. 703-706.
7. Kitazawa, K., 1993. Incremental sheet metal stretch-expanding with CNC machine tools. In: Proceedings of the 4th International Conference on Technology of Plasticity. Advanced Technology of Plasticity. pp. 1899-1904.
8. Shim, M.-S. and Park, J.J., 2001. The formabiltiy of aluminium sheet in incremental forming. Journal of Materials Processing Technology. 113: pp. 654- 658.
9. Kim, Y.H. and Park, J.J., 2002. Effect of process parameters on formability in incremental forming of sheet metal. Journal of Materials Processing Technology. 130-131: pp. 42-46.
10. Filice, L., Fratini, L. and Micari, F., 2002. Analysis of material formability in incremental forming. Annals of the CIRP. 51/1/2002: pp. 199-202.
11. Jeswiet, J., Young, D. and Ham, M., 2005. Non-traditional forming limit diagrams for incremental forming. In: SheMet '05 International Conference on Sheet Metal. Erlangen, Germany. pp. 409-416.
12. Duflou, J., Tunckol, Y., Szekeres, A. and Vanherck, P., 2007. Experimental study on force measurements for single point incremental forming. Journal of Materials Processing Technology. 189: pp. 65-72.
13. Bologa, O., Oleksik, V. and Racz, G., 2005. Experimental research for determining the forces on incremental sheet forming process. In: 8th ESAFORM Conference. Cluj-Napoca, Romania. Vol. I: pp. 317-320.
14. Jeswiet, J., Duflou, J.R. and Szekeres, A., 2005. Forces in single point and two point incremental forming. In: SheMet '05 International Conference on Sheet Metal. Erlangen, Germany. pp. 449-456.

ISSN : 2455-9679
Impact Factor : 2.865

15. Bambach, M., Ames, J., Azaouzi, M., Campagne, L., Hirt, G. and Batoz, J.L., 2005. Initial experimental and numerical investigations into a class of new strategies for single point incremental sheet forming (SPIF). In: 8th ESAFORM Conference. Cluj-Napoca, Romania. Vol. II: pp. 671-674.
16. Ambrogio, G., Filice, L., Gagliardi, F. and Micari, F., 2005. Sheet thinning prediction in single point incremental forming. In: SheMet '05 International Conference on Sheet Metal. Erlangen, Germany. pp. 479-486.
17. Hagan, E. and Jeswiet, J., 2004. Analysis of surface roughness for parts formed by computer numerical controlled incremental forming. J Engineering Manufacture Part B. 218: pp. 1307-1312.
18. Allwood, J.M., Houghton, N.E. and Jackson, K.P., 2005. The design of an incremental sheet forming machine. In: SheMet '05 International Conference on Sheet Metal. Erlangen, Germany. pp. 471-478.
19. Hirt, G., Ames, J. and Bambach, M., 2006. Validation of FEA for asymmetric incremental sheet forming by on-line measurements of deformation and tool forces. Production Engineering. XIII/1: pp. 39-44.
20. Ceretti, E., Giardini, C. and Attanasio, A., 2004. Experimental and simulative results in sheet incremental forming on CNC machines. Journal of Materials Processing Technology. 152: pp. 176-184.
21. Giardini, C., Ceretti, E., Attanasio, A. and Pasquali, M., 2004. Analysis of the influence of working parameters on final part quality in sheet incremental forming. In: 3rd International Conference and Exhibition on Design and Manufacturing of Dies and Molds, 7th International Symposium on Advances in Abrasive Technology. Bursa, Turkey. DM 2004-13.