SOME CONSIDERATIONS CONCERNING THE METHODS AND TECHNOLOGIES OF INCREMENTAL FORMING

Catalin Coman[1]

[1]"Gheorghe Asachi" Technical University of Iasi, Department of Machine Manufacturing Technology, Blvd. Mangeron, No. 59A, 700050, Iasi, Romania

Corresponding author: Coman Catalin, catalin.coman06@gmail.com

Abstract: Incremental sheet metal forming is a technique which uses CNC tools to form sheet metals. The method is not applicable for mass production but found to be very useful in small batch quality production. The study includes fundamentals of incremental sheet metal forming, classifications, tools used and effect of various parameters such as plane anisotropy, tool size and shape, lubrication on it. The study also includes the advance methods incorporated in incremental sheet forming such as doubly curved surfaces. The multi-pass single point incremental forming is a promising technology for the sheet metal forming process, characterized by high formability, product independent tooling and great process flexibility. In this work, based on a pyramidal shape, a finite element model for the multi-pass forming process is established first. This process has been promising a flexible and inexpensive way to form sheet products. The present study sheds light on the differences in deformation mechanisms between SPIF and ADSIF. Finite element analysis is performed to simulate deformation in the two processes and a detailed analysis of the deformation history is presented. It is shown that the presence of the supporting tool in ADSIF elicits substantial differences in the plastic strain, hydrostatic pressure and shear strains as compared to SPIF.

Key words: SPIF, ADSIF, finite element analysis, pyramidal shape, multi-pass forming process.

1. INTRODUCTION

The method of incremental sheet metal forming is a technique which uses CNC tools to form sheet such as doubly curved surfaces, [1, 11]. The multi-pass single point incremental forming is a promising technology for the sheet metal forming process, characterized by high formability, product independent tooling and great process flexibility. In this work, based on a pyramidal shape, a finite element model for the multi-pass forming process is established first. Unlike simplifications in previous studies, with the process of three-dimensional coordinates in numerical controlled machining code, the tool trajectory in this finite element model is obtained by a java parameterized application, based on a simple algorithm developed especially for the multi-pass single point incremental forming process, [2]. This process has been promising a flexible and inexpensive way to form sheet products. Which have important industrial applications with a high ratio of weight/strength, [3]. Single-point incremental forms (SPIF) uses one small hemispherically ended tool moving along a predefined toolpath to locally deform a completely peripherally clamped sheet of metal such that the sum total of the local deformations yields the final desired shape of the sheet. While SPIF is characterized by greater formability than conventional forming processes, it suffers from significant geometric inaccuracy, [16]. Accumulative double-sided incremental forming (ADSIF) is a substantial improvement over SPIF in which one hemispherically ended tool is used on each side of the sheet metal. The supporting tool moves synchronously with the forming tool, therefore acting as a local but mobile die. ADSIF results in considerably enhanced geometric accuracy and increased formability of the formed part as compared to SPIF, [4]. The maximum forming angle is the most used criterion to express the material formability limit in the case of single point incremental forming (SPIF) process, [5]. Titanium alloys possess low formability and high flows stresses and are difficult to form without using thermal aid to reduce the flow stress, [7].

2. METHODS AND TECHNOLOGIES OF INCREMENTAL FORMING

2.1 Hammering

One of the oldest processes in sheet incremental forming is Hammering. This process was initially done manually but with the technological developments it can be done in a modern CNC. Nowadays, Hammering takes advantage of the robotic technology and it uses a robotic arm that controls the movement of the tool and punches the sheet, which is clamped in a support frame, in circular trajectories descending step by step in each round, [8, 15, 16].

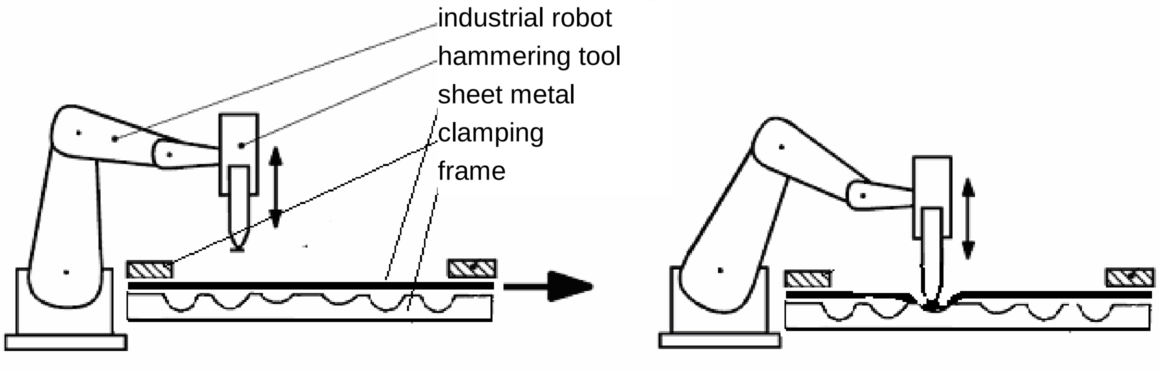

Fig. 1. Principle of the incremental hammering by an industrial robot, [6]

2.2 Multi-point forming (MPF)

The production of a panel by Multi-point Forming (MPF) technology is very similar to the forming process with solid dies. Where the latter uses two opposite solid dies that are pressed on a sheet metal blank to shape it into a particular geometry, the MPF technology replaces the solid die by a matrix of several punches with specific geometry that are adjustable in height by means of linear actuators, in order to be able to change to diverse kind of shapes in a relative short period of

Time, [8, 15].

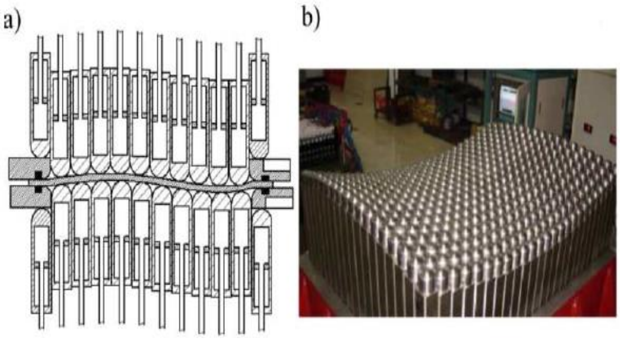

Fig. 2. Reconfigurable surface tooling:(a) multi-punch stamping die; (b) multipoint forming press machine YAM8-315, [12]

2.3 Shot Peen Forming

Shot Peen Forming is a dieless process performed at room temperature, where by small round steel shot impact the surface of the work piece. Every piece of shot acts as a tiny peening hammer, producing elastic stretching of the upper surface and local plastic deformation that manifests it self as a residual compressive stress.The shot impacts are statically distributed and they are usually made of steel balls which are accelerated using compressed air though a nozzle. The shot peen forming process is ideal for forming large panel shapes where the bend radii are reasonably large and without abrupt changes in contour so it is widely used in aircraft industry, [8].

2.4 Laser Forming Process

Laser Forming Process, figure 3, is based in thermal stresses that are induced onthe blank (clamped in a structure) by laser irradiation on the sheet metal, [8, 15]. The thermal stresses induce plastic strains resulting in bending or buckling of the material. This process can also be used to make repairs or modifications in sheet metal components, [8, 15].

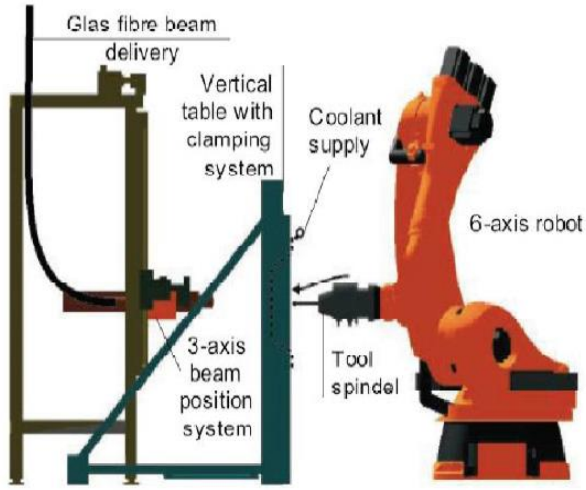

Fig. 3. Laser forming, [11]

2.5 Water Jet Forming

The Water Jet Forming is similar to the laser forming, replacing the laser by a water jet. As advantages we have: more flexibility, better surface integrity, less tooling requirements, lower equipment costs and less environmental impact. In the other hand, Water Jet Forming is less accurate, consumes more energy and takes more time than the other incremental metal forming processes [8, 15].

2.6 Spinning

Spinning can be divided in two different types of technology, figure 4, as follows: a-conventional spinning and b-shear spinning, [10, 15, 16].

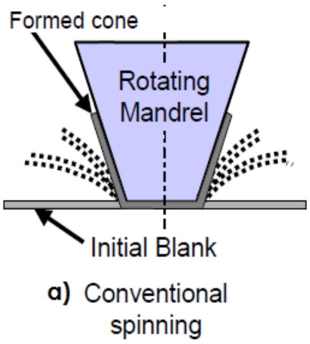

Fig. 4.Spinning variants

In Conventional Spinning, figure 4a, axisymmetric parts are gradually formed over a mandrel using a rounded tool or roller. The equipment needed is similar to a lathe to clamp the blank sheet metal on the center in a mandrel, and this set is revolved. The tool applies a localized pressure to deform the blank by axial and radial motions over the surface of the part. The tool can be manual or mechanically actuated and the tool production costs are low being suitable for producing small series because usually involves a sequence of steps. Shear Spinning, figure 4b, is quite similar to Conventional Spinning and the difference is the action which is stretching instead of bending. This fact has a major influence on the variation of thickness along the wall which follows the commonly known sine law, figure 5, [8, 10, 14, 16].
The base relation for the deformation of an element in a shear formed cone is presented in the relation (1) and the terms involved presented in figure 5.

$$t_f = t_i \sin\alpha \qquad (1)$$

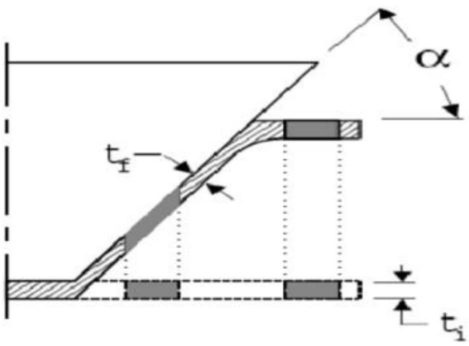

Fig.5. Deformation of an element in a shear formed cone, [8]

2.7 Single Point Incremental Forming

Single Point IncrementalForming (SPIF) gives a new important contribute to incremental forming processes like Spinning and stretch expanding which is the capability of produce non-axisymmetric parts.The blank sheet is clamped in a universal stationary blank holder and the forming tool describes the contour of the desired geometry controlled by a regular CNC machine, Fig. 6. The tool rotates and could perform a round or helical path, [8, 9, 12, 13].

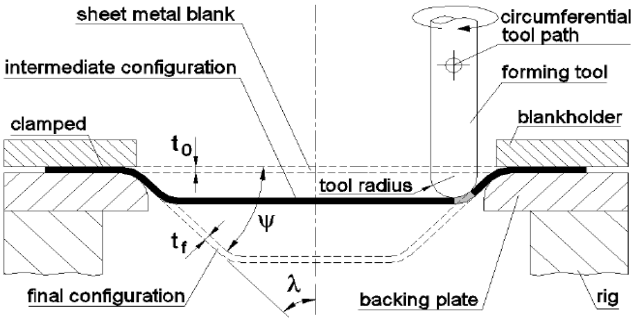

Fig. 6. Schematic representation of a cross section view of SPIF process, [8]

2.8 Incremental Forming with Counter Toole

The Incremental Forming with Counter Tool (IFWCT) is a variation of SPIF that does notuse backing plate, and instead a counter tool is utilized that makes the same trajectory of the main tool, figure 7, [8, 10, 13].

2.9 Two Point Incremental Forming

In Two Point Incremental Forming (TPIF) the blank is clamped in the blank holder which can be adjusted in the Z axis. The forming tool is similar to the tool in SPIF and performs a trajectory of the outer surface of the part, from top to bottom of the geometry. TPIF can be separated in two categories: with partial die, figure 8 and with full die, figure 9, [8].

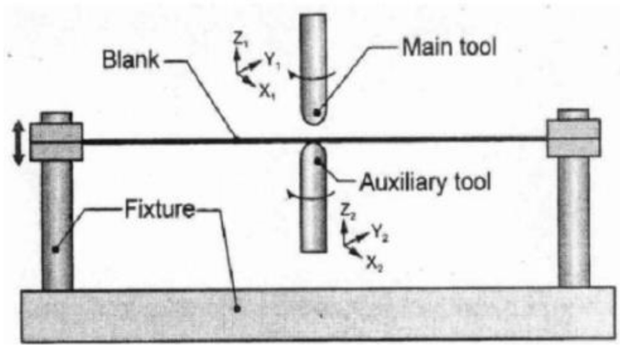

Fig. 7. Schematic representation of Incremental Forming with Counter Tool, [8]

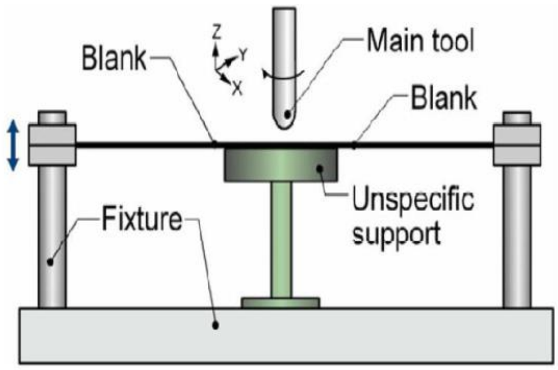

Fig. 8. TPIF (partial die), [8]

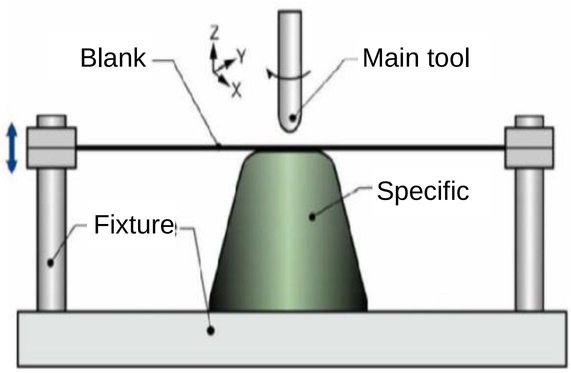

Fig. 9. TPIF (full die), [8]

2.10 Multistage Forming

For every material with a specific thickness, a maximum forming angle can be determined by means of a simple cone forming test in were parameters like incremental step size and tool diameter are kept constant. Using conventional tool paths, when a sufficiently portion of a workpiece has a wall angle that exceeds this maximum angle, the part will fail during processing, figure 10, [8].

2.11 Hybrid forming process

One of the most unavoidable limitations of the Incremental Sheet metal forming technique is its time consumption. One of the examples of the hybrid forming technique is combination of the stretch forming and the incremental sheet forming. For every different design, different strategy of forming is used. Here formation of the dome shape with groove over its surface is explained, [1, 14].

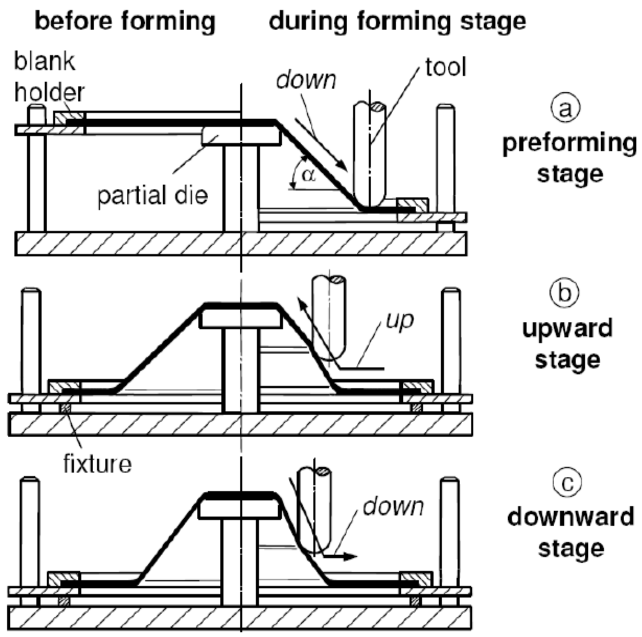

Fig. 10. SPIF Multistage strategy, [8]

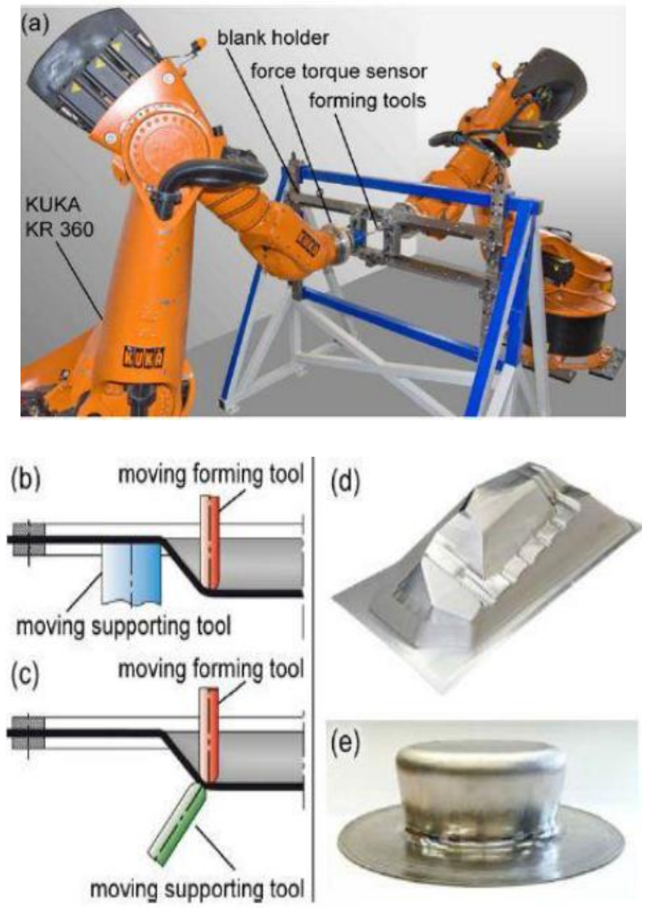

Fig.11. (a) Roboforming setup, (b) P-DPIF, (c) L-DPIF, (d) Complex automobile part, (e) A part with negative wall angle (-7°), [1]

3. CONCLUSIONS

For low batch and quality production, Incremental sheet metal forming technique is proves to be the most efficient method. Due to the use of CNC mills, accuracy of the parts can be increased and more complex parts can be produced. The method is most suitable for the prototype production. In this work the thickness reduction, formability, strain distribution over the sheet surface, influence the tool radius and shape on the surface precision of work piece, the forming limits and stress condition analysis of the metal blanks, thinning at the corner radius of workpiece, defects study,influence of heat treatment in formability will be studied. The methodology of incremental sheet metal forming process has a high potential in terms of getting plastic deformation of parts of complex shapes. The process application is limited although recent research has tried to improve this situation. According to research conducted literature, there does not exist the opinion on optimum technological equipment for this process. Another point can be that there aren't insufficient proofs of technological forces that occur in the process and timely and effective methods for their determination.

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Received: May 20, 2015 / Accepted: December 10, 2015 / Paper available online: December 20, 2015 © International Journal of Modern Manufacturing Technologies.