NEW FORMING TECHNOLOGIES FOR LOW AND MEDIUM VOLUME PRODUCTION

COMAN Liviu[1], IANICI Draghita[1], IANICI Sava[1]
[1]"Eftimie Murgu" University of Resita, Faculty of Engineering, l.coman@uem.ro

Keywords: technology, incremental forming, hydroforming, metal sheet

Abstract: This descriptive paper presents the principles and the main characteristics of some new forming technologies which can be used in a low and medium volume manufacturing process, such as liquid impact forming, incremental forming, combined methods, etc. Both cases of forming metal sheets and tubes are described, containing references to the equipments and to the technological indicators. These new forming methods gives the possibility to create flexible forming facilities, without dies, capable of producing complex shaped surfaces, while applying generic tooling.

1. INTRODUCTION

In the field of sheet metal forming, the production of prototypes or parts in low batch sizes is being realized by high priced conventional forming processes. The lack of flexibility as well as high investment costs clearly point out the limits of conventional sheet metal forming for these parts. Recently, different kinematics-based sheet metal forming processes have been developed. In most cases these methods only require simple dies or supports.

New methods of forming sheet metal are now at a stage where it is possible to make either custom manufactured parts or to manufacture small batch production quantities, with very short turn around times from design to manufacture. It was predicted in 1991 that with the increase in automation metal forming equipment would become more flexible.

Inspiration for the emerging processes is usually found in traditional forming methods. These conventional processes are typically constrained as far as achievable part geometry is concerned and require dedicated tooling and dies. CNC hardware and software have reached a mature state of development enabling the development of new sheet metal forming processes. The new forming methods give the possibility to create flexible forming facilities, without dies, capable of producing complex shaped surfaces, while applying generic tooling. The ultimate goal is 'dieless forming'.

In case of sheet metal products, incremental sheet metal forming represents a reliable fabrication method for prototypes and low volume production as described in [6].

2. INCREMENTAL SHEET FORMING

Incremental sheet forming (ISF) is a flexible process in which a sheet of metal is formed by a progression of localised deformation. It is flexible because specialised tooling is not required; a simple tool moves over the surface of the sheet such that a highly localised plastic deformation is caused. Hence a wide range of 3D shapes can be formed by moving the tool along a correctly designed path. The principle goal which motivates the development of ISF is the possibility of forming sheet metal without the need to manufacture specialised dies. This is particularly advantageous for low and medium volume or customised production.

Recently, some works have studied the feasibility of some forming strategies that aim at improving the accuracy of parts formed by ISF, identifying tool path 'overbending' as a promising approach to improve the accuracy of a part [5,6,7].

The two most common configurations of ISF are single-point incremental forming (SPIF) and two-point incremental forming (TPIF). In SPIF the sheet is formed with a single indenter while it is clamped around its edges (fig.1), whereas in TPIF the sheet is formed against a male or female die, a support post or a second mobile indenter (fig.2). In both cases the most common tool paths are contours or spirals of increasing depth, following the profile of the product.

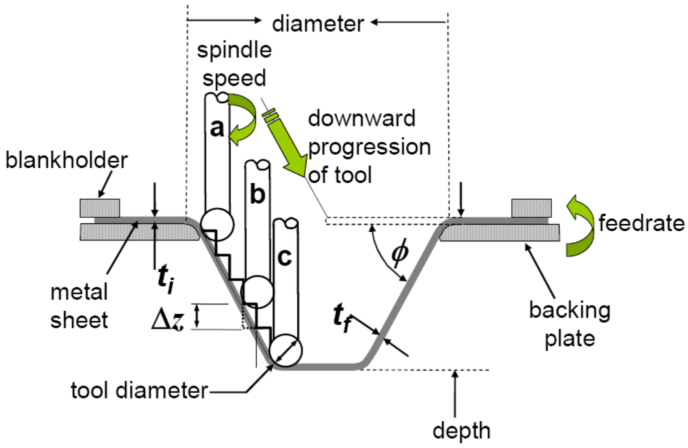

Fig.1. The principle of Single Point Incremental Forming [3]

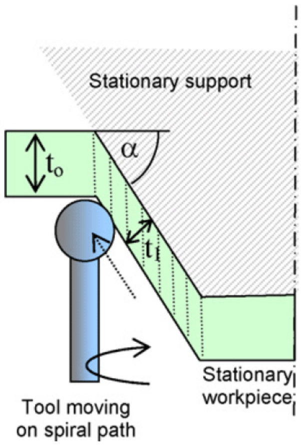

Fig.2. The principle of Two Point Incremental Forming [5]

The incremental step-down size (step size, Δz) is the amount of material deformed for each revolution of the forming tool (similar to cut depth in machining). The step size affects the machine time and the surface quality. The step size parameter is set in CAM software.
Feedrate is the speed the forming tool moves around the mill bed (similar to cut rate in machining). The feedrate had a direct impact on the machine time for forming. It is measured in mm/minute. The feedrate parameter is set in CAM software and is then varied on the mill.
The spindle rotation speed is the speed at which the tool rotates. The spindle rotation speed varies the heat generated at the contact point between the material and the forming tool. The spindle rotation speed is also set at the mill.
The angle between the horizontal, undeformed sheet metal and the deformed sheet metal is defined as the draw angle or forming angle (φ). This is the line of the deformed blank sheet metal as shown in fig. 1. The forming angle can be used as a measure of material formability. The maximum angle (φmax) is the greatest angle formed in a shape without any failures. The forming angle is set within CAD software.
Despite extensive research in ISF over the last decade, the deformation mechanism is not fully understood. An understanding of the deformation mechanism is important to allow accurate numerical models of the process 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. A review of the numerical and experimental work on the deformation mechanics and the limitations of this work are given in [2].
For a wider industrial use of ISF it is mandatory to find solutions to the main limitations of the process, which are: the long process time, the sheet thinning, the limited geometrical accuracy and the lack of dedicated process planning and modelling tools.
The forming strategy with its forming parameters has a main influence on the process result. Depending on the material and the geometry being formed, parameters like the infeed, the forming velocity or the tool path especially affect the part's accuracy. Additionally, the sheet is subject to springback.

3. COMBINED FORMING PROCESS

In this section, a new combined process is analysed, the combination of ISF and stretch forming (SF).

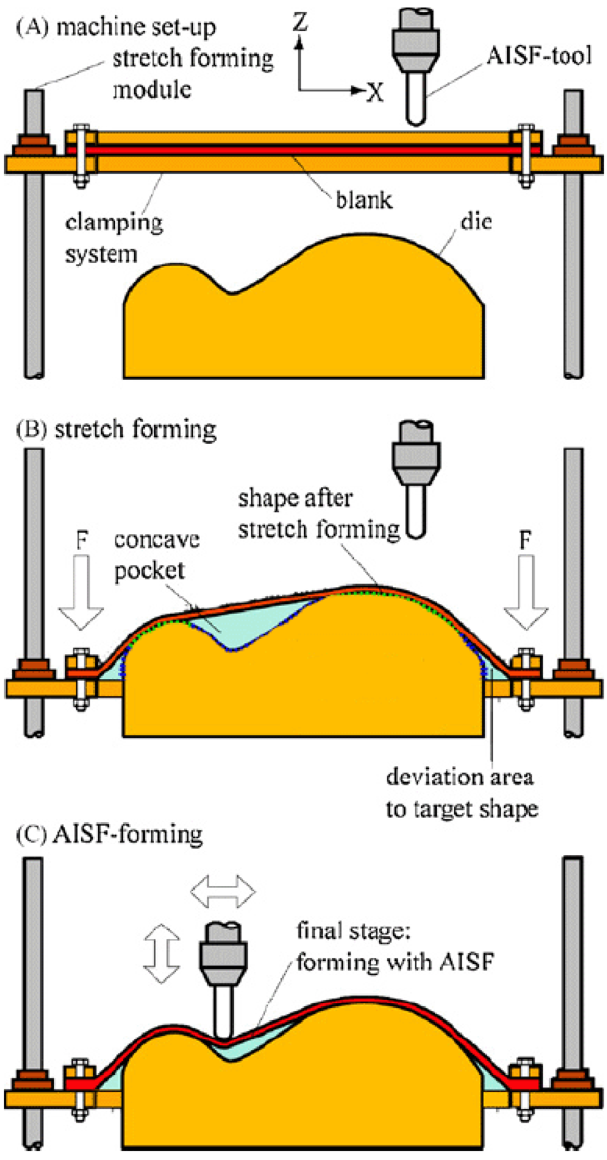

Fig.3. The principle of combined process [8]

The concept of the new combined process is illustrated in fig. 3, which indicates that stretch forming is used to create a pre-form in a first forming step. Stretch forming will not yield the final part geometry (otherwise the process combination would not be necessary). Hence, features such as pockets, corrugations or grooves that are not formed during SF are formed using ISF.

The following advantages are expected from the combination of ISF and SF:

a. The process time of ISF increases with the surface area covered by the tool path. The process time for stretch forming scales with the total height of the part. Hence, the combination of ISF and SF is expected to have a shorter process time for shallow parts with a large surface area.

b. For a given part, ISF and SF yield a different distribution of sheet thinning. If a pre-form can be produced by SF that leaves more sheet thickness for part features such as pockets than would be available if the same pre-form is produced by ISF, the process combination should yield less thinning in the pocket areas compared to ISF. Thus, the process combination should offer new possibilities to overcome the thinning limits of ISF.

c. Stretch forming is known to yield parts with a good accuracy due to the tensile state of stress [7]. ISF could benefit from stretch forming in two ways: by creating a pre-form using SF that would be more accurate than a pre-form manufactured by ISF; by superimposing tensile stresses during ISF, i.e. by applying stretch forming simultaneously to ISF in order to reduce the residual stresses induced by the cyclic bending and unbending.

d. In the same way as the forming time is reduced, the time needed for the simulation of the process should be smaller for SF + ISF compared to ISF. Hence, process planning and optimisation would become more viable for the process combination than for ISF.

The statements above do not hold for arbitrary parts. It will be necessary to identify part geometries for which the process does offer these advantages.

Future research must focus on the effect of the process combination of SF and ISF on the dimensional and geometrical accuracy and the forming limits.

4. INCREMENTAL BULK FORMING

In an incremental bulk forming process, regions of the workpiece experience more than one loading and unloading cycle due to the action of one set of tools within one production stage.

Processes that do not satisfy the definition above are called die-defined processes because the shape of the finished parts is totally defined by the geometry of the dies. In contrast, in incremental processes the shape is at least partially generated by the kinematics of the tools.

The separation of incremental sheet and incremental bulk processes is somewhat problematic. As another definition, incremental bulk forming processes are those which apply to workpieces which are not, initially, thin in one dimension – i.e. which do not have the characteristics of sheet, tube or wire. Three initial workpiece shapes will be considered: billet (brick shape or plug shape); long product (bars or rods); rings.

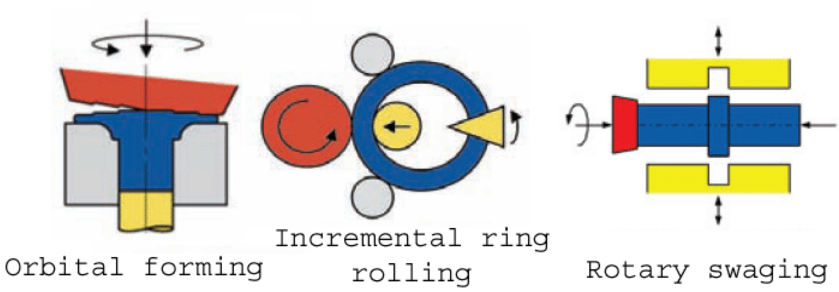

Fig.5. Some examples of incremental bulk forming

Orbital forming is an example of an incremental process with a continuous deformation sequence and mainly uniaxial compressive stresses. This is a mature technology, related to ring rolling and the processes of tube nosing and flaring. Figure 5 illustrates a schematic of the process [1].

While in conventional cold forming the force is applied over the entire surface of the part, in orbital forging it is applied only on a small segment. The orbiting upper die rolls over the part. Therefore, friction is reduced substantially and the metal can flow much more easily in the radial direction (rolling friction instead of sliding friction).

5. A NEW TECHNOLOGY IN TUBES FORMING

Hydroforming has revolutionized sheet metal stamping and tube forming. It can expand, bend, bulge, and change a simple pipe into geometric shapes without a hint of wrinkling. One disadvantage of conventional hydroforming is an initial investment in special presses and tooling. Another drawback is the additional cycle time needed to produce a single part—up to three times longer than conventional stamping. This can result in decreased output and smaller profits. However, the cost of tooling required is comparable to the cost of a conventional single-station, offline forming die.

Liquid impact forming, a patented process developed by Greenville Tool & Die Co., Greenville, Michigan, uses a conventional stamping press with a liquid medium to manufacture parts that otherwise would require hydroforming. This process doesn't replace either conventional stamping or hydroforming, but rather fills the gap between them. It allows certain products to be manufactured at a fraction of the cost compared to conventional hydroforming.

With this process, single parts—replacing entire assemblies—can be manufactured. This can reduce the need for welding and assembly operations. In addition, because liquid impact forming uses a conventional stamping press, cycle times can be up to 20 times faster than conventional hydroforming. Piercing and forming can be done in a single-station liquid impact die. Liquid impact tooling also can be placed inline with conventional stamping dies.

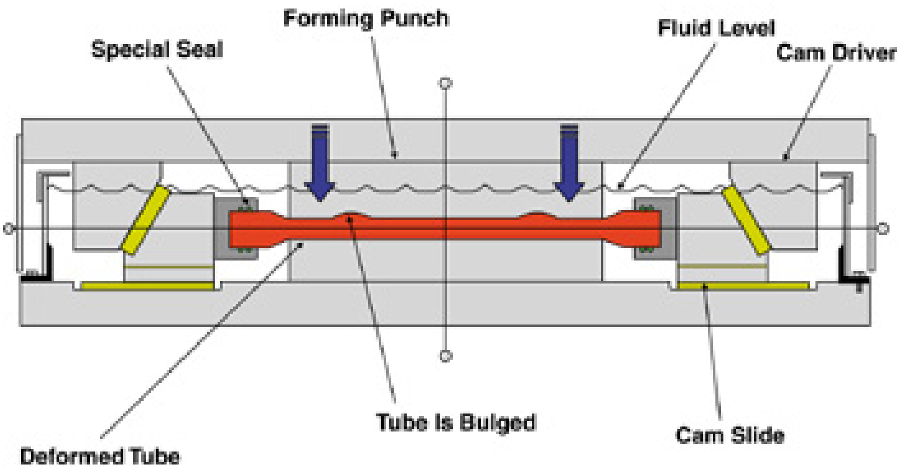

Fig.4. The principle of liquid impact forming [4]

In liquid impact forming, a tube is submerged in water, the ends are capped off, and the tube is squashed in a specific area. The displaced water reshapes, bulges, or supports the tube in a specific area. At the bottom or any point during the press stroke, pressure is released by a mechanical pressure release valve and the finished part is removed (fig.4).
This process can turn a simple tube into a variety of straight, twisted, or curved shapes. Depending on the final product shape, it may be necessary to prebend the tube to fit into the liquid impact die. Because the tube is filled with and supported by liquid, it can be pierced at the bottom of the press stroke, reducing the tendency for the metal to cave in around the pierced hole.
Water has many advantages in the metal forming industry:

- it does not compress—it fully supports the areas of a tube that otherwise might wrinkle during compression.
- it can conform to any geometric configuration.
- forming with liquid can promote good stretch distribution. This maximizes the amount of stretch that can occur within a given boundary. Even stretch increases the total strength of the formed product.
- it is readily available and inexpensive.
- it can be combined with biodegradable rust preventive.

Unlike conventional hydroforming, liquid impact forming doesn-t inject water into the tube or compress its original length. The amount of bulging that can be achieved is limited to the stretchability, formability, and tube material thickness. Products requiring severe bulging and extensive metal flow don-t lend themselves to liquid impact forming and are more suited for conventional hydroforming. Also, the amount of deformation that takes place is controlled by the amount of liquid displaced when the tube is squashed.
Liquid impact forming is not intended to replace conventional hydroforming, but to offer a viable alternative. Straight, simple tubes whose shape circumferences must be changed from a simple circle to a square, octagonal, or polygonal shape are prime candidates for liquid impact forming.

6. CONCLUSIONS

Even metal working with incremental techniques has falled into shadow in the 20th century, nowadays are indications of a renaissance in this technology. Incremental forming features high flexibility of the machinery by kinematical shaping processes, lowcosts, reduced forces and the possibility of working with less formable materials. Today incremental sheet and bulk metal forming is applied in various industrial manufacturing processes. Because of the high product quality that can be achieved with this technology, it is used especially for high-end applications in the automotive and aerospace industry. Several new processes that have recently been developed show current existing interest in these techniques. But if incremental forming should be used on a larger scale again in the near future, there are some challenges to be mastered. Complex kinematics demand new machinery and drive concepts as well as fast and reliable controls. Existing limitations of the processes should be eliminated by an advanced design.

As shown in this paper the production of complex parts by incremental metal forming is advantageous in many cases. With the possibility of achieving net-shape quality, this approach features technological and economically interesting alternatives to other manufacturing processes. To tap the full potential, the traditional knowledge of the craftsmen has to be converted into new processes and equipment that will be designed for future requirements.

BIBLIOGRAPHY

1. Groche, P., Fritsche, D., Tekkaya, E. A., Allwood, J. M., Hirt, G., Neugebauer, R., **Incremental Bulk Metal Forming**, Annals of the CIRP Vol. 56/2/2007, 635 – 656

2. Hagan, E., Jeswiet, J., **A review of conventional and modern single point sheet metal forming methods**, IMECHE part B, J. of Engineering Manufacture, 2003 vol 217 No B2. Pp 213 - 225

3. Ham, M., Jeswiet J., **Single Point Incremental Forming and the Forming Criteria for AA3003**, Annals of the CIRP Vol. 55/1/2006,

4. Hendrick, A., **The how, what, and why of liquid impact forming**, The Stamping Journal nr.1/2002, www.thefabricator.com

5. Jackson K., Allwood J., **The mechanics of incremental sheet forming,** Journal of materials processing technology 2 0 9 (2 0 0 9) 1158–1174

6. Jeswiet, J., Micari, F., Hirt, G., Bramley, A., Duflou, J., Allwood, J., **Asymmetric Single Point Incremental Forming of Sheet Metal**, Annals of the CIRP Vol. 58/2/2008

7. Powell, N., Andrew, C., **Incremental forming of flanged sheet metal components without dedicated dies**, IMECHE part B, J. of Engineering Manufacture, 1992, vol. 206, pp 41 – 47

8. Taleb Araghi B., Manco G.L., Bambach M., Hirt G., **Investigation into a new hybrid forming process: Incremental sheet forming combined with stretch forming**, CIRP Annals - Manufacturing Technology 58 (2009) 225–228