INCREMENTAL FORMING AS A METHOD OF MANUFACTURING CORRUGATED DIAPHRAGMS

Florin NEGOESCU[1], **Oana DODUN**[2]

ABSTRACT:

This paper introduces a new incremental sheet metal forming process and explains the improvements in this forming process and the adaptation at the corrugated diaphragms forming. The research reported in this paper concentrates on incremental sheet forming with an industrial robot. The equipment is based on a strong arm robot and a moving forming table, where a sheet metal blank is attached. The tool slides on the surface of the sheet and forms it incrementally to the desired shape. The robot is capable of 5-axis forming, which enables forming of inwards curved forms. By moving a hammering tool over a sheet metal fixed by a frame, a three-dimensional workpiece can be produced without using any special die plate. As the forces on the handling equipment are very low compared to other forming processes, a common industrial robot can be used to move the hammering tool. Thus sheet metal parts can be produced with cost-effective equipment.

KEYWORDS: lincremental sheet forming, dieless forming, corrugated diaphragms

1. INTRODUCTION

The dieless forming technology is one of the latest innovations in the field of sheet metal forming. This novel technique offers the possibility of obtaining in a quick and easy way sheet metal parts without needing traditional machines and methods such as dies and presses.

Incremental sheet forming (ISF) is a term describing a set of sheet metal forming methods. Common to these methods is ability to form non-symmetrical geometries with simple or no tooling and low costs. ISF does not require expensive tools for producing complicated sheet metal parts and the forming equipment is suitable for large variety of products without major changes or expensive investments. It is a method for prototyping and manufacturing sheet metal products in short series.

The method was originally developed for rapid prototyping of stampings and sheet metal panels and now it is used by several industries and also for small lot production. The variations of ISF can be divided into two main categories: forming of the convex surface or the concave surface. In this process the blank remains stationary and forming occurs using CNC control of the tool.

The convex surface forming was the first variation of ISF. Known as Dieless NC Forming, it was introduced in Japan by Matsubara in 1993, as a method for prototyping and manufacturing sheet metal products in short series.

Prototypes, short series and pre-series can be obtained in a great variety of materials and formats such as steel, stainless steel, aluminium and titanium.

With this new technique, parts of complex geometries can be obtained directly from the CAD 3D model of the part. The part is formed as a result of little deformations that are printed successively on located areas of the sheet metal.

The addition of these little deformations generates the final form of the part. The process is completely automatic thanks to the action of a spherical head core which makes pressure on a small area of the sheet metal surface and thanks to a numerical control system that rules the movements.

Traditional sheet metal forming requires expensive dedicated dies, both positive and negative, where each die mimics one side of the desired part. Modern manufacturing industry strives to be flexible and be able to respond to customer needs.

Cost efficiency and high quality are key factors in product development. Sheet metal

forming in short series has not been cost effective, and thus possibilities to use sheet metal have been limited. In many components plastic could be replaced with sheet metal, and the result would be visually attractive, economically reasonable, mechanically strong and recyclable.

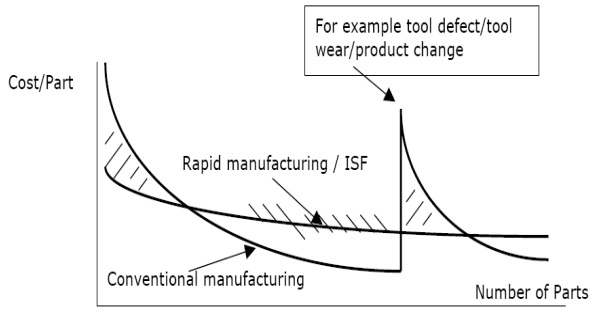

Figure 1. Cost model for Rapid Manufacturing ISF and conventional manufacturing process comparison [4]

The cost comparisons between traditional manufacturing processes and rapid manufacturing processes affects of product change, tool wear and tool defects should be taken in account. This means that after the first break even point in cost curves there are several other possible break even points. In figure 1 such base case has been described.

2. MECHANICS, EQUIPMENT AND SOFTWARE FOR ISF

The mechanics of ISF is similar to that of conventional spinning, shear forming and flow forming in that the deformation mechanism is localized to a small region under the forming tool. Deformation occurring in forming products is due to local stretching and bending occurs at clamping position. Strain conditions ranges from pure uni-axial stretching to bi-axial stretching and dominant mode of failure is due to excessive thinning of the sheet in areas overstretched.

Incremental sheet forming (ISF) is a method, where a spherical numerically controlled tool is used to push the sheet to the desired shape against a simple support tool (figure 2). ISF can be done with a modified CNC mill or a special machine built for this purpose. In this study an industrial robot has been used for forming. A sheet is clamped securely to a blank holder and the forming tool attached to a robot arm forms the sheet incrementally.

Table1. Mechanical Evaluation of ISF

	Min Requirement	Max Requirement
Maximum dimension	20mm	5m
Surface finish	'good'	'Very good'
Wall angle	0	90
Geometric tolerance	0.5mm	5mm
Minimum feature radius	1mm	50mm
Sheet thickness	0.4mm	3mm

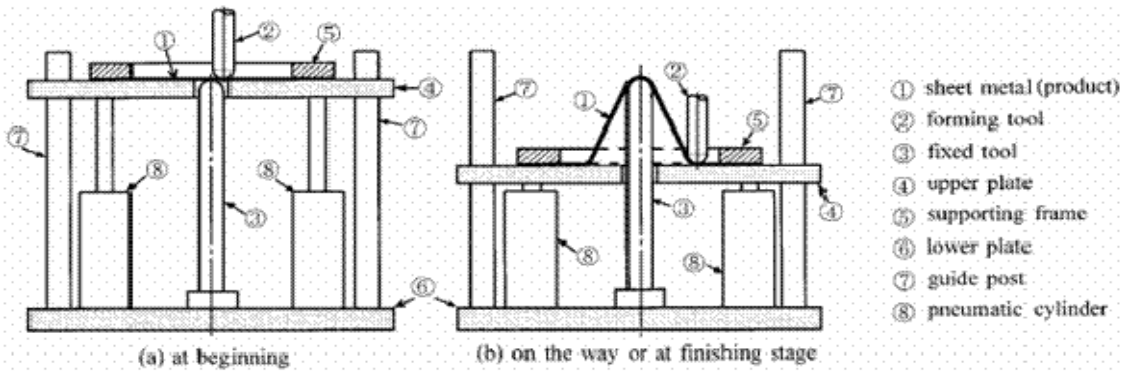

Fig. 2. Setup for incremental sheet metal forming

3. FORMING THE CORRUGATED DIAPHRAGMS

The elastic diaphragms are pieces of circular form on a planed or profiled surface, integrated in a contour, which, under the pressure applied on one face, gives visible and easily measurable distortions.

In as part as the technological process of obtain the diaphragms, operation for form's sake corrugated he is one of the most importance operationes, considering the hold

over the feature on which has it form corrugated and her geometry. Applicable areas for that type of diaphragm are sow large, so that the modest enumeration for contrivances in which construction are used, may contain some tenthly appliances and are include example part of the most variety technical fields, beginning with the regulators of temperature used at hatcheries and end with measure indicators of high and speed of aeroplanes. It is important to remark the fact that, the diaphragms may also be used as separating tool between two medias and for elastic tightens, allowed the transmission of movement from medias with pressure or vacuum.

Using an industrial robot in ISF creates new possibilities in manufactured corrugated diaphragms. A robot arm can be equipped with a hammering tool and can thus be used efficiently during whole production process. Because the robot has a wide working range, this method is suitable for manufacturing large parts, such as vehicle parts, as well as deep forms.

The geometry of the piece is converted from 3D CAD data through CAM to NC data. The simple support tool is placed under the work holder and the blank sheet is formed against the support tool. Moving tool, or Z-tool, slides on the surface of the sheet and presses the sheet into desired form. The Z-tool is computer controlled. The forming principle is shown in Figure 3 and 4.

Because of the limits of increasing the flexibility of conventional sheet metal forming described above, new flexible forming processes have been developed in recent years. With these processes the desired geometry is produced by repeated local forming. As the sheet metal forming happens step by step, these processes are known as incremental forming processes.

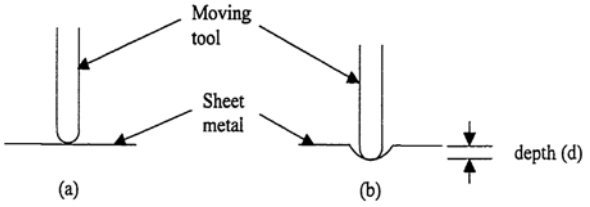

Figure 3. A schematic view of the tooling to define the depth (d) during forming process
a – initial position; b – position of the tool during forming process

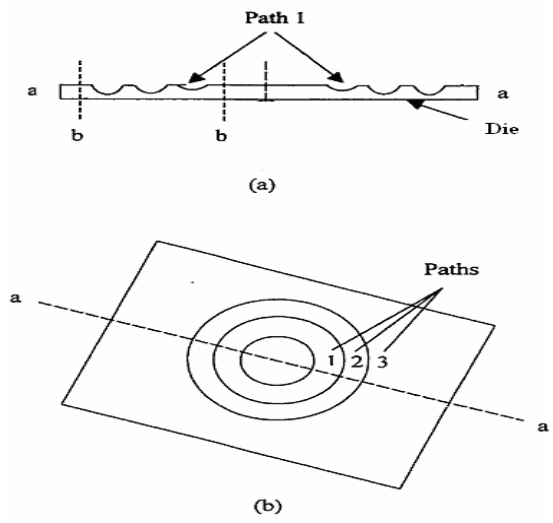

Figure 4. The form of the frame for the corrugated diaphragms

In comparison to conventional forming processes the forming capacity needed is much smaller.

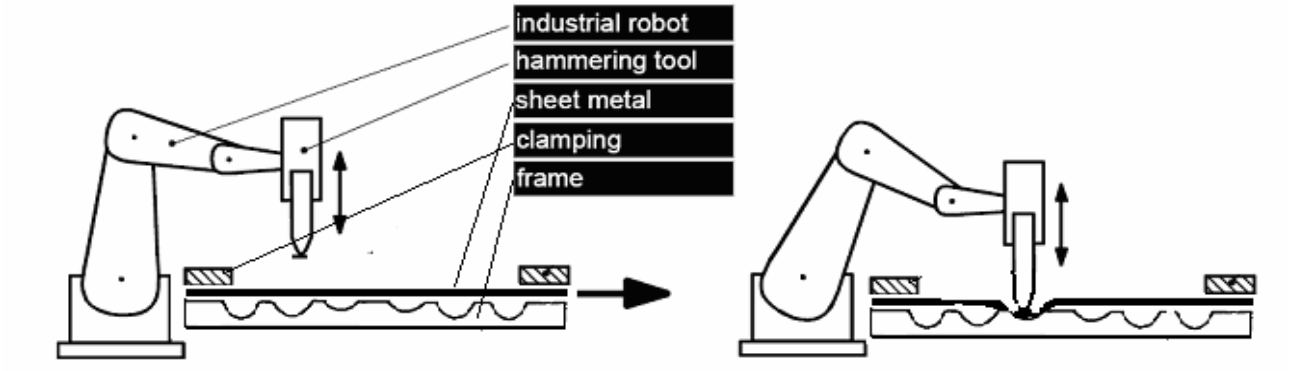

Figure 5: Principle of the incremental hammering by an industrial robot

The new incremental forming process works like this: The sheet metal is being deformed by a great amount of sequently executed hammer punches while the industrial robot is moving the hammering tool over the plate. Thus the desired geometry is produced. For these purposes the sheet metal is initially clamped into a frame. Afterwards the sheet metal is deformed along a calculated path. The principle of the new process is shown in figure 5.

3. CONCLUSION

The conclusions presented below have been developed from the results of this work.
- The first conclusion is, incremental fonning is a feasible process;

- Only small reaction forces affect the handling equipment due to the fact that the deformation forces are generated by the inertia forces of the punch and not by the handling equipment itself. Thus a commercially available industrial robot can be used for the movement of the forming tool.

- The area of deformation is smaller because of the inertia of the sheet metal near the defomation zone. There-fore a deformation without any die plate under the sheet metal can be realized;

- Due to the fact that the hammering tool raises from the sheet metal after each;

- The production process of ISF is shorter than in conventional production methods. The forming paths are generated directly from the 3D CAD file, and often no tooling is needed. If a support tool is required, the same 3D CAD file can be used for making the support tool. In many cases the support tool is not needed and the process is shorter. If corrections are needed, the CAD file is changed, the programme is converted again and the next piece can be manufactured. It is noticeable that corrections to the model are easy to make in any part of the process. The support tool materials are inexpensive and easy to work, and a new support tool can be made fast when needed;

- Incremental forming is best suited to make small batches of an item because of its slow manufacturing time and low cost-effectiveness per part. Incremental forming is best suited to make small batches of an item because of its slow manufacturing time and low cost-effectiveness per part;

- The accuracy is affected by spring back, the shape of the formed part, the shape and size of the tool, the forming toolpath, material and thickness of the blank ;

- Using the ISF methot for manufacturing the corrugated diaphragms the posibilities of change the form of the corrugated it is facile. Though the process can form almost as intricate shapes, compared to the conventional sheet metal forming process, the tooling costs can be as low as 5-10%

REFERENCES

[1] 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);
[2] G. HIRT, S. JUNK, N. WITUSKI, Incremental sheet forming: quality evaluation and process simulation, Proceeding of the 7th ICTP Conference, 925-930 (2002);
[3] T.J., KIM, D.Y YANG. Improvement of formability for the incremental sheet metal forming process. International Journal of Mechanical Sciences, vol. 42, pp. 1271-1286, 2001;
[4] Seppo SYRJÄLÄ. *Rapid Manufacturing, Manufacturing Process of the Future*. Presentation in Desing World (in Finnish Suunnittelun maailma) Seminar, Wanha Satama, Helsinki, March 10, 2004.

AUTHORS

[1]Lecturer, Ph.D, Florin NEGOESCU, Technical University „Gh. Asachi" of Iaşi, Departament of Machine ManufacturingTechnology, Romania, negoescu@tcm.tuiasi.ro
[1]Lecturer, Ph.D, Oana DODUN, Technical University „Gh. Asachi" of Iaşi, Departament of Machine ManufacturingTechnology, Romania, oanad@tcm.tuiasi.ro