A Review of the Sheet Metal Forming Methods Using Reconfigurable Dies

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ABSTRACT
Reconfigurable Manufacturing Systems (RMS) are designed for rapid change in the system configuration, their machines and controls. In the field of sheet metal forming could be identified a number of such types of methods. In the paper are analysed these deformation methods, to point out their advantages and applications.
Key words: *reconfigurable manufacturing systems, sheet metal forming, incremental forming, spinning, hydroforming, multipoint deformation*

1. Introduction

Reconfigurable Manufacturing Systems (RMS) is designed for rapid change in the system configuration, their machines and controls. In this way RMS offer an additional approach of adjusting production capacity and functionality quickly to new products as well as in response to market changes.

From economical point of view, RMS go beyond the objectives of mass, lean, and flexible manufacturing and allow flexibility not only in producing a variety of parts, but also in changing the system itself.

In the field of metal forming processes, the application of reconfigurability is limited due to the production characteristics:

- a great variety of shapes and dimensions;
- a great quantity of parts;
- each part demands a specific tool, each change in part design demands a new tool;
- less flexibility in comparison with machining, where the same set of cutting tools can be used to produce a wide variety of finished shapes.

In the last decades important efforts were made to increase the flexibility in metal forming processes. This led today to could identify some reconfigurable systems for this technology.

As it follows it will presented some of the metal forming processes which belong to the reconfigurable technology.

2. Incremental Forming

In this method, a simple geometry tool (a hemispherical tool) is mounted on a vertical axis of a machine and the motion of this tool along the tool-path progressively forms the sheet metal to its final shape by insertion of small regions of controlled plastic deformations. For the process, universal 3 or more axis CNC machining centre can be used.

Two main variants of the dieless incremental forming process are known: the so-called "negative forming process" and the "positive forming" process.

In negative incremental forming (Figures 1 and 2), a ball punch moves on a sheet metal, according to a programmed tool path. The sheet is clamped at the periphery by bolts on a support frame.

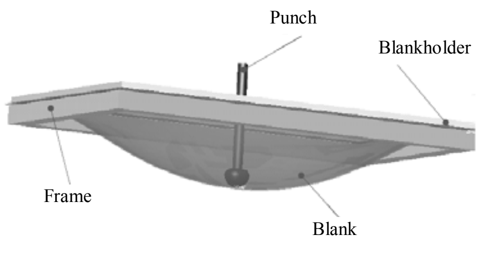

Fig. 1. Negative Incremental Forming Process [12]

In positive incremental forming (figure 3) the blank 2 is put on the upper plate 3, and is fastened on all sides by a fixed plate 5, which can move along the guide pillars 7. A forming tool 1 presses the sheet into a punch core 4 and moves along the contour line under the control of the machine until the required shape is formed.

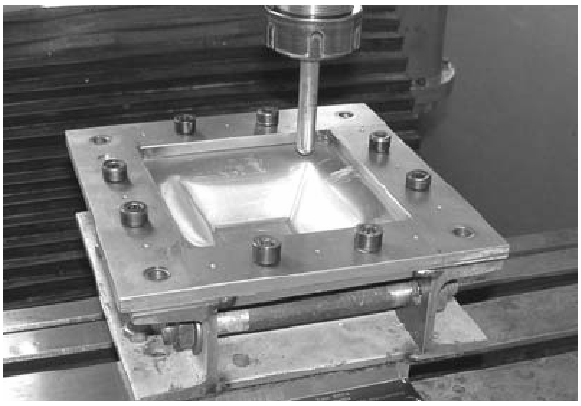

Fig. 3. Set-up system for negative incremental forming [13]

During the forming process, the computer controls the tool’s movement in x-y direction and the gradual movement in z direction. Within the layer of the same height, the forming tool makes a curvilinear movement on the x-y plane. When a layer is finished, the tool moves down a small distance of h along the z-axis and continues to process the next layer till all layers are formed. 8 is the piece obtained.

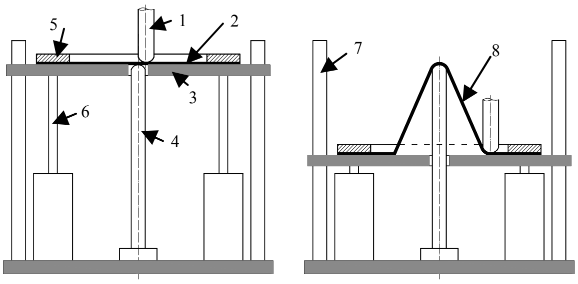

Fig. 3. Positive Incremental Forming Process [20]

Compared to the traditional forming process, incremental forming process has higher extensibility, fineness and smoothness of the work piece. In addition, it can be used for machining complicated curved surfaces, which cannot be done by the traditional method (complex shape out of metal sheet up to 2.4 meters by 1.4 meters at various thicknesses ranging from 1-5 millimeters). Another advantage of dieless forming is that the tooling costs are 5–10% of conventional stamping. The forming process is slow. Thus this process is suitable for low volume production in the magnitude of 1–500 pieces per month. With this new process, tools could be discarded and dieless forming machines can be employed to produce parts upon demand. This system is ideally suited for rapid prototyping as development time and tryout costs are greatly reduced.

No hard tooling is required and design CAD data can be transferred to the machine controller easily. Depending on the part size, a prototype panel could be produced in approximately one week upon receipt of the CAD data.

The accuracy is affected by spring back, the shape of the formed part, the shape and size of the tool, the forming tool path, material and thickness of the blank. Accuracies of between 1,5mm and 2 mm have been achieved.

3. Spinning with Reconfigurable Mandrel

Spinning sheet metal is an excellent method for quickly prototyping round hollow metal shapes.

A force is applied uniformly to the sheet metal by rotating the blank and its intended form (mandrel) at very high rpms, thus the sheet metal is deformed evenly without any wrinkling or warble. The spinning process allows for the rapid production of multiple parts as well as quick reiteration since only the mandrel need be modified.

To overcome this drawback, it was proposed a new method of deformation in which the mandrel is reconfigurable (figure 4).

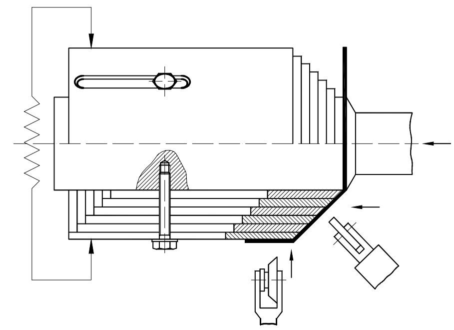

Fig. 4. Spinning with reconfigurable mandrel [23]

For this, the mandrel is composed from a number of telescopic bushes, which move axial, according to present configuration. The configuration is established numerical, depending upon the piece geometry. The method is still in experimental stage.

4. Hydroforming with Reconfigurable Punch

Hydroforming constitutes a subgroup of sheet metal forming processes utilizing a pressurized forming medium. The process of sheet hydroforming, unlike conventionnal stamping, involves supporting the bottom of the sheet with a bed of viscous fluid during the forming process.

The advantages of the sheet hydroforming process are numerous and the process is receiving significant attention from both the automotive and aerospace industries. Advantages, include improved formability of the blank due to the applied pressure by the fluid, low wear rate of dies and punch, a better distribution of plastic deformation when compared to conventional sheet metal forming, significant economic savings associated with the decreased tooling, and the potential for reducing the amount of finishing work required.

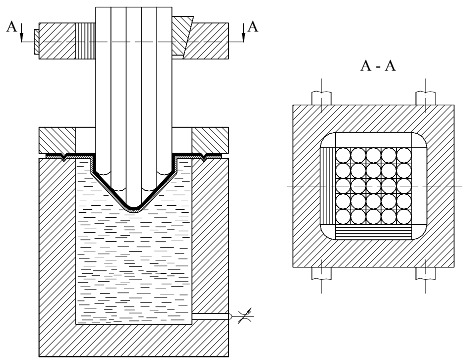

Fig. 5. Hydroforming with reconfigurable punch [23]

A method, who offers a great flexibility in comparison with the conventional one, is presented in figure 5. In this method, the punch is composed from an array of pins, which are independently shifted in vertical direction, according with the piece profile. The configuration is established numerical, depending upon the piece geometry. The active part of the pins is covered with a polymer or rubber to prevent the dimpling phenomenon. The method is also in experimental stage.

5. Multipoint Deformation

Discrete die forming is an engineering concept developed more than fifty years ago, initially designed for sheet metal forming. Using a geometrically reconfigurable die, precious production time is saved because several different products can be made without changing tools. Also a lot of expenses are saved because the manufacturing of very expensive rigid dies is reduced.

The working surface of the die is made up of hemispherical ends of individual pins, where each pin has a square cross section and can be independently displaced.

Depending on a type of application, discrete die forming is applied in two variants:

- for stretch forming. In this case only a single die is necessary (figure 6). The material is deformed according to two main types of methods depending upon the force sequences. The first is simple stretch forming in which the material is simply wrapped around the tool and is used for simply curved geometry. The method is rarely used because the blank is not uniformly deformed and the spring back is very important. The second is stretch forming with a supplementary material deformation and could be applied in three manners:

a. pre-stretch and wrap, (figure 7, a). In this method sheet metal is first pre-stretched with force F_1 above its yield stress, and then is wrapped around the tool while maintaining the force F_1 constant;

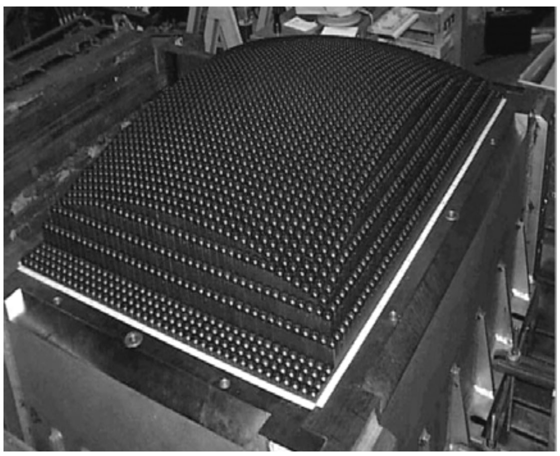

Fig. 6. Discrete Die for stretch forming [4]

b. wrap and post stretch (drape forming), (figure 7, b). The sheet metal is first wrapped around the tool and after that an additional tensile stress is imposed on the part;

c. pre-stretch, wrap and post-stretch (stretch-wrap forming) (figure 7, c). Sheet metal is first pre-stretched with force F_1 above its yield stress, and then is wrapped around the tool and finally an additional tensile stress F2 (post-stretch) is imposed on the part;

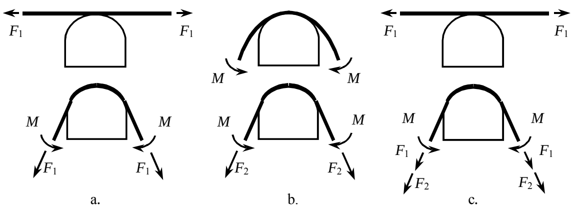

Fig. 7. Types of operations in stretch forming [17]

- for deep drawing. In this case in literature the name of method is called multipoint deformation (MPF) and is used two opposite dies (figure 8).

The movement of each punch is controlled independently by MPF press, and MPF is a flexible processing technique. One of the main advantages of MPF is that the forming path of metal sheet can be adjusted freely, and a sheet product can be manufactured along an optimum forming path with least risk of forming failure.

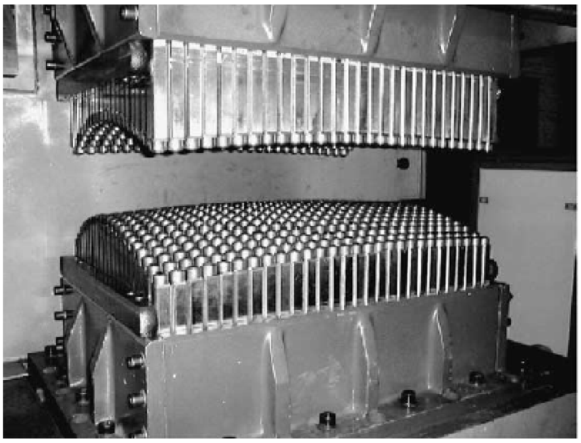

Fig. 8. Multipoint deformations die [24]

Multipoint forming of sheet metal has the following characteristics: deformation of materials in MPF is not as large as that in forming; in-plane forces are smaller than those in forming and bending deformation is the predominant deformation; contact boundary is a multi-point, discontinuous one between sheet and punches dies, and is much more complicated than that of forming.

This method is most suitable for the forming of large dimension shell-like parts, such as the shell of ships and large vessels, etc.

6. Conclusions

Analyse presented in this paper, based on important numbers of references, clarified the new tendencies in the field of success manufacture by plastic deformation of curved, multi-axial, multi-ply parts. These new methods of deformation even actually are used mainly as rapid prototyping techniques, have a great number of advantages because their reconfigurable character.

7. Acknowledgements

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Studiu privind tehnologiile de deformare cu matrite reconfigurabile

Rezumat

Sistemele reconfigurabile (RMS) de fabricare permit adăugarea, înlăturarea sau modificarea unor capabilități de proces specifice controlului, software-lui sau structurii maşinii pentru a răspunde modificărilor cerute de tehnologie sau de piață. În domeniul tehnologiilor de deformare plastică se pot identifica câteva astfel de procedee. În lucrare se prezintă o detaliere a acestor tehnologii, cu evidențierea principalelor avantaje şi domenii de aplicații.

Ein Berichte des Blechs, das Methoden Mit Reconfigurable Matrize Bildet

Zusammenfassung

Reconfigurable Fertigungssysteme (RMS) sind für schnelle Änderung in der Anlagenkonfiguration, in ihren Maschinen und in den Kontrollen bestimmt. In auffangen des Blechs konnte der Formung gekennzeichnet werden eine Anzahl von solchen Arten Methoden. Im Papier werden diesen Deformation Methoden, ihre Vorteile und Anwendungen zu unterstreichen analysiert.