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Virtual Compensation of Springback in Sheet Metal Deformation Using Reconfigurable Multipoint Die

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Abstract

Forming with reconfigurable multipoint dies is a flexible manufacturing stamping technology which it uses discrete punches to materialize the continuous 3-D surface of the active elements. In the paper is presented an algorithm for springback compensation in deformation with multipoint reconfigurable die and the results of the virtual compensation of this phenomenon using the finite element method, as the central part of the proposed algorithm.

Key words: *reconfigurable systems, multipoint deformation, sheet metal forming, springback*

1. Introduction

In sheet metal forming the springback is a major problem. When the tool are released after the forming stage the part springback due to the internal stresses action. Because the part does not meet the geometrical requirements, the tools are manually redesigned so that the shape deviations due springback are compensated. This is a complex and costly operation. At present-time it is a trial-and-error process of manufacturing tools, making a prototype product, measuring it, modifying CAD data and reworking the stamping tool. Using the reconfigurable multipoint forming (RMF) the die reworking is change with die reconfigurability.

The surface tooling in reconfigurable multipoint forming (RMF) is based on the concept of a die continuous surface discrete approximation (Figure 1). It consists of a number of closely spaced multiple rigid surface tool elements, known as pins, each of which is a surface element of an expected contour.

The heights of the pins can be adjusted to approximate the desired surface shapes either manually or using a computer control. A variety of surface shapes can be realized by properly adjusting the heights of surface tool elements because such a tooling is reconfigurable. The total time involved in the tool set up is considerably less than that involved in the development of a hard tool.

As it follows an algorithm and some results about springback compensation in RMF process will be presented. The algorithm has as the central part the finite element method.

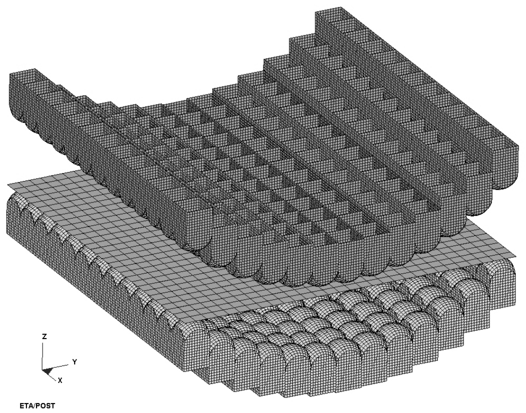

Fig.1. *Reconfigurable surface tooling*

2. Simulation Model

A simple geometry tool for obtaining a simple curved plate with an interior radius of 95 mm, a width of 120 mm (maximum depth is 21.345 mm) and a length of 130 mm will be considered.

The curved plate was divided in a number of 30x30 elements using the CAD technique. Using the method presented in [4] the contact points between the pins and the curved plate were calculated. Using the contact points coordinates it was built the tool using the FEM program Dynaform (figure 1).

In the simulation two pins networks which materialize the punch and the die were used. In the networks are used square pins, with a radius of each pin end of 7.07 (Fig. 1).

The FE mesh consists of 4-node Belytschko-Tsay shell elements, with five integration points through the thickness of the sheet [9]. The Belytschko-Lin-Tsay shell element are based on a combined co-rotational and velocity-strain formulation.

The material used in experiments was mild steel, with 1 mm thickness. The yielding of the material was modelled using a power law:

$$\sigma = K\,\varepsilon^{n} \qquad (1)$$

in which: K is the material characteristic; n – hardening exponent. In simulation the n-value = 0.22 and K = 648 MPa. The R-values were set to: R_{00} – 1.87; R_{45} – 1.27; R_{90} – 2.17. The Coulomb friction law was used with a friction coefficient of 0.125.

The punch speed was 100 mm/second.

The blank was a rectangular plate with the dimensions of 130x130x1 mm and the mesh consists of 900 finite elements.

The tooling was modelled as rigid surfaces. The geometrical model of die-punch tool was composed from two working networks with 100 pins for each network, 10 rows on x-direction and 10 rows on y-direction. The pins are disposed face to face, both on x-direction and y-direction. The mesh consists of 258804 numbers of finite elements. No rubber interpolator was used and no blankholder.

3. Algorithm for Springback Compensation

The algorithm used is based on the displacement adjustment (DA) method [4].

The idea is to measure the part, and to calculate the distance between the final part and the desired shape of the part. The surfaces of the tools are then displaced with the same distance, but in the direction opposite to the springback deformation [5].

The part is characterized by the reference surface (RS). The reference surface could be defined analytic or in discrete form. In RMF is important to find the contact points between the pins and the part, to could configure the tool. A method for this was developed [10].

Virtually, using FEM and the program Dynaform, the tool is configured using the coordinates of the contact points. After the forming operation, the reference surface (RS) is obtained. The reference surface is characterized by the reference mesh (RM). After the tools are removed, the part will springback resulting the springback mesh (SM0). The difference between the (RM) and the (SM0) represents the value of springback (VSB). If (VSB) is less or equal with an acceptable tolerance then the process of springback is finished. If not, using (VSB) the (RS) is changed in the direction opposite to the springback deformation.

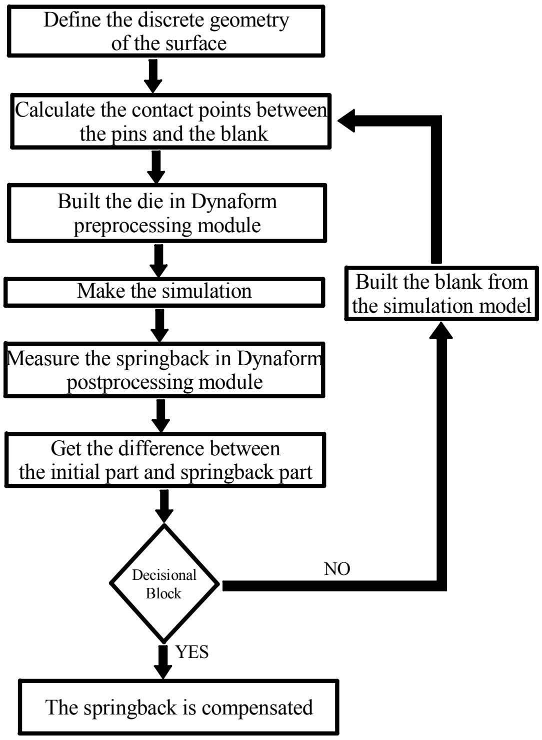

Fig. 2. *Algoritm for springback compensation in RMF*

The reference surface is modified obtaining the reference surface at the increment i (RSI). The contact points are recalculated for this new (RSI). The tool is modeled for increment i and the simulation is resumed. After the tools are removed, the part will springback resulting the springback mesh at the increment i (SMI).

The difference between the (RM) and the (SMI) represents the value of springback at the increment i (VSBI). If (VSBI) is less or equal with an acceptable tolerance then the process of springback is finished. If not, the process is resumed for the next increment. The general algorithm is presented in figure 2 and it is shown in figure 3.

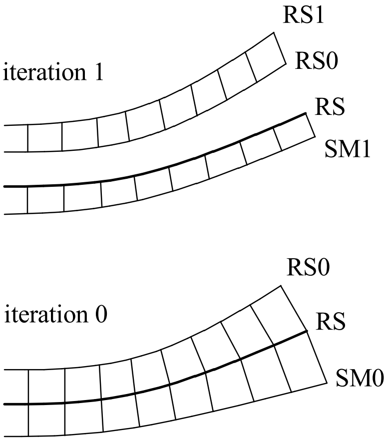

Fig. 3. *Application of DA method*

4. Results of Applied Algorithm

The reference surface (RS) characterized by the reference mesh (RM) and the springback meshs (SM0 and SM1) after the two stages of forming operation are presented in figure 4.

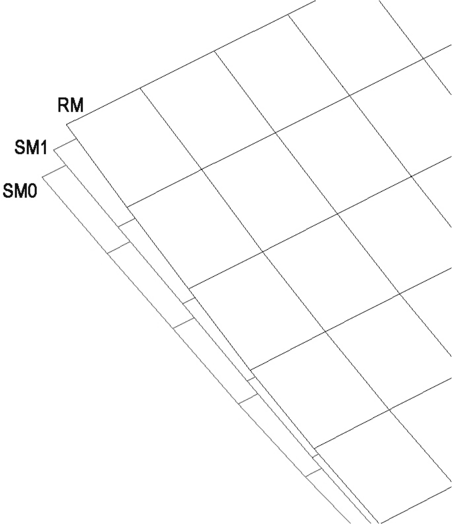

Fig. 5. The mesh before and after the two stage forming operations

The value of springback becomes 13.098 after the first forming operation, 1.547 after the first die reconfigurability (first stage of deformation) and 0.214 after the second die reconfigurability (second stage of deformation). As this value is less than one considered as acceptable tolerance of 0.25, it was concluded that the process of reconfigurability was finished. These values are measured in the parts corners as it is shown in figures 4 and 5 where the springback has the maximum values. It's clearly that these values vary in the product section, being minimum in the central part of the product.

5. Conclusions

The paper had presented an algorithm for springback compensation in reconfigurable multipoint forming. The algorithm had demonstrated his robustness and could be used for rapid configuration of such types of dies. By reconfigurability instead of reworking important advantages are obtained in terms of material expenses and productivity.

6. Acknowledgements

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Compensarea virtuală a revenirii elastice la deformarea cu matriță multipunct reconfigurabilă

Rezumat

Deformarea cu matrițe multipunct reconfigurabile este o tehnologie de presare flexibilă care utilizează poansoane discrete pentru materializarea suprafeței continui 3D a elementelor active. In lucrare se prezintă un algoritm pentru compensarea revenirii elastice la deformarea cu matriță multipunct reconfigurabilă şi rezultatele compensării virtaule ale acestui fenomen utilizând metoda elementului finit ca parte principală a algoritmului propus.

Virtueller Ausgleich von Springback in der Blech-Deformation mit Reconfigurable Mehrpunktmatrize

Zusammenfassung

Die Formung mit reconfigurable Mehrpunktmatrize ist eine flexible Herstellung, die Technologie stempelt, der sie getrennte Durchschläge benutzt, um die ununterbrochene Oberfläche 3-D der aktiven Elemente zu verwirklichen. Im Papier wird einen Algorithmus für springback Ausgleich in der Deformation mit reconfigurable Mehrpunktmatrize und in den Resultaten des virtuellen Ausgleiches dieses Phänomenes mit der Finite-Element-Methode, als das zentrale Teil des vorgeschlagenen Algorithmus dargestellt.