

Design an Experimental Reconfigurable Die for Sheet Metal Forming

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ABSTRACT

The reconfigurable surface tooling is based on the concept of discrete approximation of a die continuous surface with a number of closely spaced rigid pins. The heights of the pins can be adjusted to approximate the desired surface shapes either manually or using a computer control. In the paper are analyzed some of main parameters of the deep drawing with reconfigurable die and based on this are presented the results of the development of a reconfigurable die in the present research activity.

Key words: reconfigurable die, multi point forming, sheet metal forming, deep drawing, process design

1. Introduction

The reconfigurable surface tooling is based on the concept of discrete approximation of a die continuous surface (figure 1). The concept of discrete surface tooling was first given by Nakajima [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.

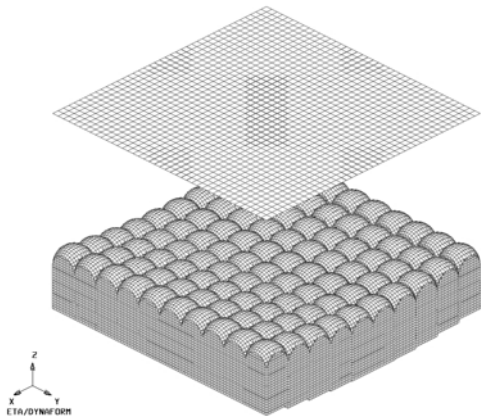


Fig.1. Reconfigurable surface tooling

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

less than that involved in the development of a hard tool. The discrete nature of the tool can be overcome by placing a polymer sheet over the pins.

The method is carried out in three variants:

- for stretch forming;
- for deep drawing;
- for punching.

For stretch forming, an extensive research work on the concept of discrete surface tooling has been carried out by Hardt et al. [2, 3, 4] at the Laboratory for Manufacturing and Productivity at Massachusetts Institute of Technology. New improvements have been proposed and applied by Walczyk et al. [6, 7], Papazian et. al. [8, 9] for forming sheet metal parts and composites. Part dimensional accuracy using closed-loop control of the shape, the different parameters influences toward the product quality and part manufacturing costs, are some important issues in their researches.

For deep drawing with reconfigurable die, the method is well known as multi point forming (MPF). In this case both die and punch are discrete and reconfigurable surfaces. Cai et. al. [19, 21], Li et. al. [20, 22] carried out researches in this direction. They developed an implicit elasto-plastic finite-element computer code to simulate the MPF process of sheet metal based on the updated Lagrangian formulation. Prediction of forming defects by controlling the spring back phenomenon is the main problem studied by these researchers.

For punching with reconfigurable die, the manufacturing process is similar with MPF. Chen et. al. [23] started with success researches in this field. They design and produced a die, whose geometry is based on 3D surface reconstruction, for multiple punching which was used in the medical field for cranioplasty.

In this paper are analyzed some of main parameters of the MPF process and based on this are presented the results of the implementation of a reconfigurable die in the present research activity.

2. Analysis of Forming Parameters

MPF process could be characterized using a series of parameters:

- shape, number and type of pins arrangement in the network (figure 2).

The pins shape could be hexagonal, square, triangle or circular.

As it is important that the contact surface between the pins to be maximum, it results that a hexagonal, square or triangle arrangement is preferably. For technological reasons a square pins network is used.

The pin ends are semispherical, with a diameter equal with the diagonal of the cross section of the pin (in practice it lies between 25 and 28 mm).

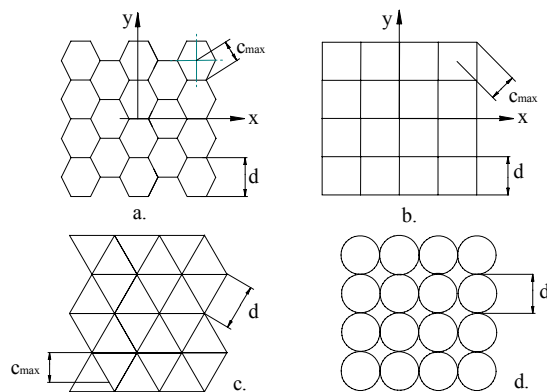


Fig.2. Types of pins networks: a. hexagonal; b. square; c. triangle; d. circular

Number of the pins depends of the dimensions of the blank and of their diameter.

- the pins height positions are the main problem in the deformation with reconfigurable tooling. These positions determine the points contact between the pins and the blank surface. Different mathematical models for pins coordinates

determination are used. In the real process it is obviously these positions to be adjusted according to the material characteristics.

- material. From the material characteristics, the thickness is the most important parameter toward the deformation process. As the material is thinner, the dimpling phenomenon is more present, with a negative impact toward the piece quality. To obtain a piece with a better shape and surface quality, it is necessary to use an interpolator between the pins and the blank (figure 3). This could be made from polymer or rubber.

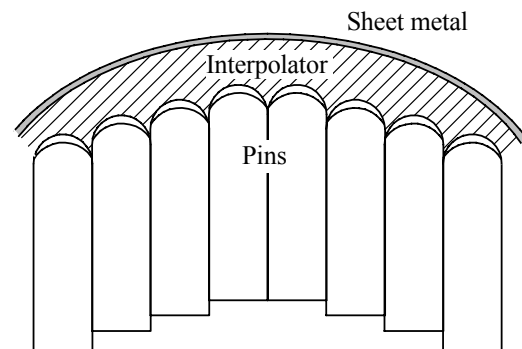


Fig. 3. MPF with an interpolator

- locking force. The die pins must be locked into position to withstanding the forming load. The slip of the pins during forming results in a loss of the die shape and respectively of the piece shape. Three methods of temporarily locking pin position are used:

- individually lock each pin;
- backfill the non-forming of the die with some moldable material;
- clamp the entire structure (side clamping) with a high force to provide each pin with frictional resistance to the high forming loads.

The first method requires as each pin be individually actuated. For a complete control this is most suitable.

Side clamping increases the speed of die development. The clamping force could be applied on one direction or in two directions (figure 4).

The minimum force required to clamp the pins, in the case of one direction locking, is:

$$N = n \cdot \frac{F_d}{2 \cdot \mu_{static}} \quad (1)$$

	$F_p = \frac{F_a}{2 \cdot \tan \theta}$
<p>Toggle mechanism</p>	<p>θ – the tip angle of toggle links</p>
	$F_p = p_0 \cdot A$
<p>Hydraulic clamping</p>	<p>p_0 – the pressure; A – the cylinder area</p>
	$F_p = \frac{F_a \cdot (\cos \phi - \mu_A \cdot \sin \phi)}{[(\mu_A + \mu_B) \cdot \cos \phi + (1 - \mu_A \cdot \mu_B) \cdot \sin \phi]}$
<p>Mechanical wedge clamping</p>	<p>ϕ – the wedge angle; μ_A, μ_B – the friction coefficients</p>
	$F_p = \frac{N \cdot V \cdot H \cdot B}{g \cdot c}$
<p>Piezoelectric clamping</p>	<p>N – the number of piezoelectric laminations; V – the voltage on the lamination; H, B, g – the dimensions of each laminations; c – the piezoelectric voltage coefficient.</p>
	$F_p = \frac{\alpha_c \cdot (T - T_0)}{\left[\frac{1}{A_p \cdot E_p} - \frac{1}{A_c \cdot E_c} \right]}$
<p>Thermally clamping</p>	<p>α_c – the frame thermal coefficient; A_p, A_c – the contact areas between the pins and the frame; E_p, E_c – the elastic modulus of the pins and frame material.</p>
<p>Tab. 1. – Clamping systems of discrete die element matrix: F_p – clamping force; F_a – input force</p>	

where: F_d is the forming, vertical force; n – number of pins; μ_{static} – friction coefficient.

In table 1 are presented different types of die element matrix clamping systems. Detailed presentation of each of these is finding in [6].

The condition of clamping is as N from formula (1) to equal clamping force F_p from table 1.

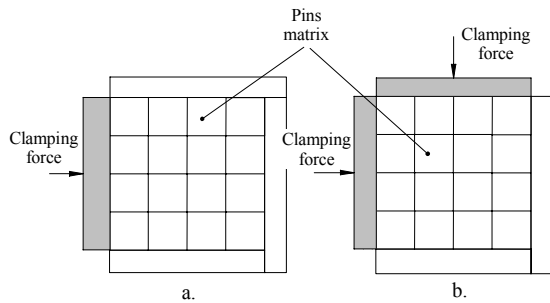


Fig. 4. Types of matrix clamping: a. on one direction; b. on two directions

3. Development of a MPF Die

Simulation of MPF process, figure 5, has proved the viability of method, even when in process is not using an interpolator. For future experimental researches in Metal Forming Laboratory of Manufacturing Department, was developed a MPF die.

The design of one of the active part of the die is presented in figures 6-8 and is based on a mechanical wedge clamping system using the appropriate formula presented in table 1.

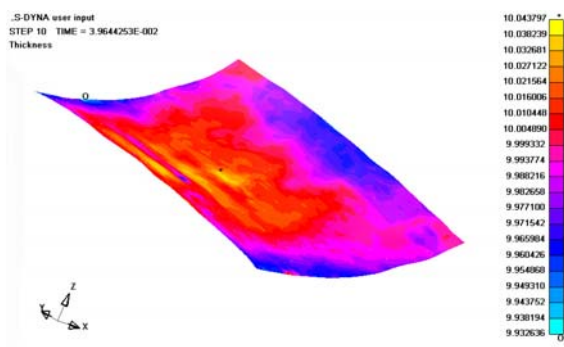


Fig. 5. Results of MPF process simulation

The die is composed from 200 numbers of pins, 100 for each active part. The clamping is assured by two mechanical wedges for each active part. The input force for is give by four nut bolts, two for each direction. Each pin is manually

actuated using a nut bolt, arranged to the base surface of the pin (figure 6). The pin position is mathematical determinate according with surface geometry. A numerical program was developed for this [14].

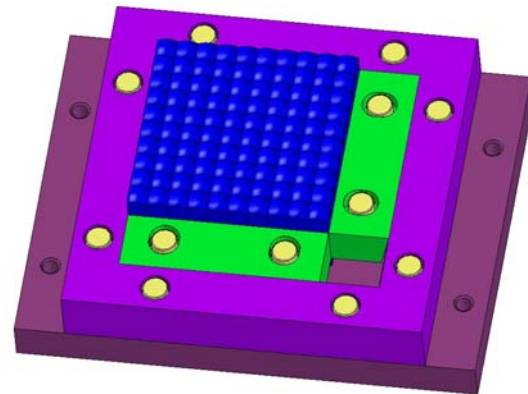


Fig. 6. An active part of the MPF die

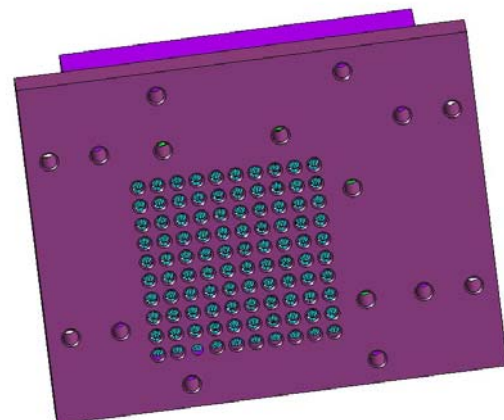


Fig. 7. Base plate of the active part of the MPF die

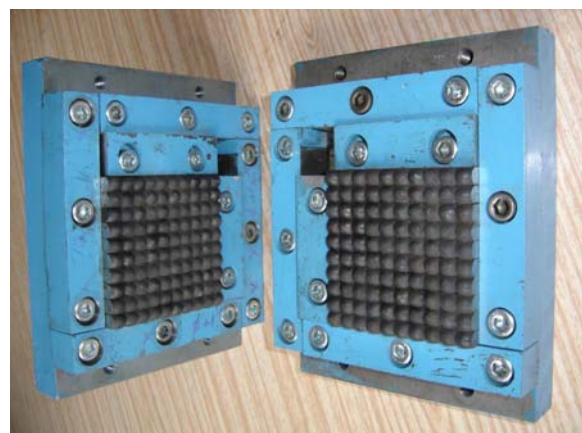
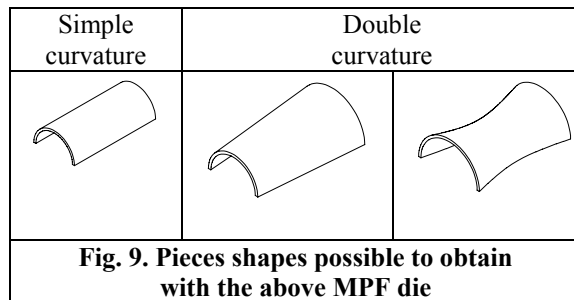


Fig. 8. Manufactured active parts of the MPF die

For the shape control is used an automated system, consists of a computerised robotic arm, who measures the spatial position of each pin.



Different types of parts which are intent to obtain are presented in figure 9.

5. Acknowledgements

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Proiectarea unei matrițe reconfigurabile pentru ambutisarea tablelor

Rezumat

Suprafața reconfigurabilă a elementelor active ale matriței se bazează pe conceptul de aproximare discretă a suprafeței cu un număr de pini spațial poziționați. Înălțimile pinilor pot fi modificate fie manual fie computerizat pentru a defini geometria de lucru. În lucrare sunt analizați o parte din parametrii procesului de ambutisare folosind matrițe reconfigurabile și pe acesta bază este prezentat un echipament proiectat în vederea desfășurării unor cercetări ulterioare.

Entwerfen Sie Einen Experimentellen Reconfigurable Matritze für die Blech-Formung

Zusammenfassung

Die reconfigurable Oberflächenwerkzeugausrüstung basiert auf dem Konzept des getrennten Näherungswerts einer ununterbrochenen Oberfläche des Matritze mit einer Anzahl von nah steifen Raumstiften. Die Höhe der Stifte kann justiert werden, um die gewünschten Oberfläche Formen manuell zu approximieren entweder oder mit einer Computersteuerung. Im Papier werden einigen von Hauptparametern der tiefen Zeichnung mit reconfigurable Matritze analysiert und gegründet auf diesem werden die Resultate der Entwicklung eines reconfigurable Matritze in der anwesenden Forschung Tätigkeit dargestellt.