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# Comparative Study for Single-Curved Plates Forming with Continuous and Reconfigurable Die-Punch Assembly

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## Abstract

*In this paper, an alternative solution to conventional press forming of plates is proposed. In fact, the traditional continuous die-punch tool is replaced with a specially die-punch assembly based on the "discrete die-punch" reconfigurable tooling concept. This comparative numerical study is applied to a single-curved plate and is made with LS-DYNA FEM soft, Dyna-Form module. The Belytschko-Lin-Tsay shell element based on a combined co-rotational and velocity-strain formulation was chosen to analyze the elasto-plastic process with complex geometrical nonlinearity. The geometrical modeling of the reconfigurable die-punch assembly request calculations for the characteristic profiles coordinates of working surfaces, while for continuous die-punch modeling are necessary only the necessary radius of the desired shape and plate thickness. A series of conclusions obtained from the numerical simulation of the press forming process for a cylindrical plate shape using continuous, respectively reconfigurable die-punch tool are shown at the end.*

*Keywords: press forming, reconfigurable die-punch assembly, single-curved plates*

## 1. Introduction

Conventional press forming is the process to bend flat plates into curved plates using hydraulic press with a continuous die-punch tool for each shape of desired curved plates. Recently, press forming of the large-sized plates is made on special equipments based on the "discrete die-punch" reconfigurable tooling concept. In fact, the monolith die-punch was replaced by a series of forming pins placed next to each other (Fig.1), their height being controlled mechanically or hydraulically. Reconfigurable die-punch tool whose shape can be rapidly changed offer an attractive reduction in time and cost of plates forming production process.

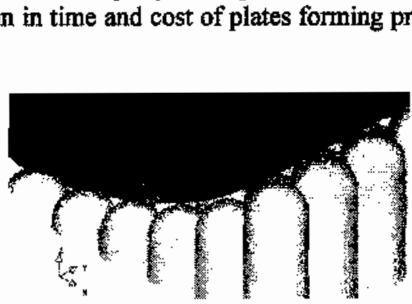

Fig.1 Forming pins for a reconfigurable die-punch tool

## 2. Simulation models

The following specific parameters were used into this comparative simulation study:

- punch stroke, $p = 207.11$ mm;

- material properties for plastic deformation range according to Ludwick law $s = k e^n$, where $k = 754$ MPa and $n = 0.18$;

- the input data for elastic material, density, Young's modulus and Poisson's ratio, according to implicit program values for steel;

- anisotropic coefficient equal to 1 and abrasion coefficient between plate and die-punch surfaces equal to 0.125.

- 1120 x 2000 mm flat plate model with 10 mm thickness for both assembly configurations. Due to symmetry, the geometrical model for each is only for a quarter of real deformation case.

The geometrical modeling of the reconfigurable die-punch tool requests calculations for the characteristic profiles coordinates of working surfaces. Because of semispherical shape of the pin ends that materialize the working surfaces, it is necessary to apply corrections that will count for the displacement of contact points between pins and curved plate.

Two working plates with 66 pins for each materialize the geometrical model of reconfigurable die-punch tool. The pins are disposed face to face, both on $x$-direction and $y$-direction.

On the basis of characteristic profiles coordinates resulted from PINCENTER program [1], were obtained the characteristic profiles of die, punch and flat plate. The input and output data are presented in table 1 and a cross section through die-plate-punch is shown in figure 2.

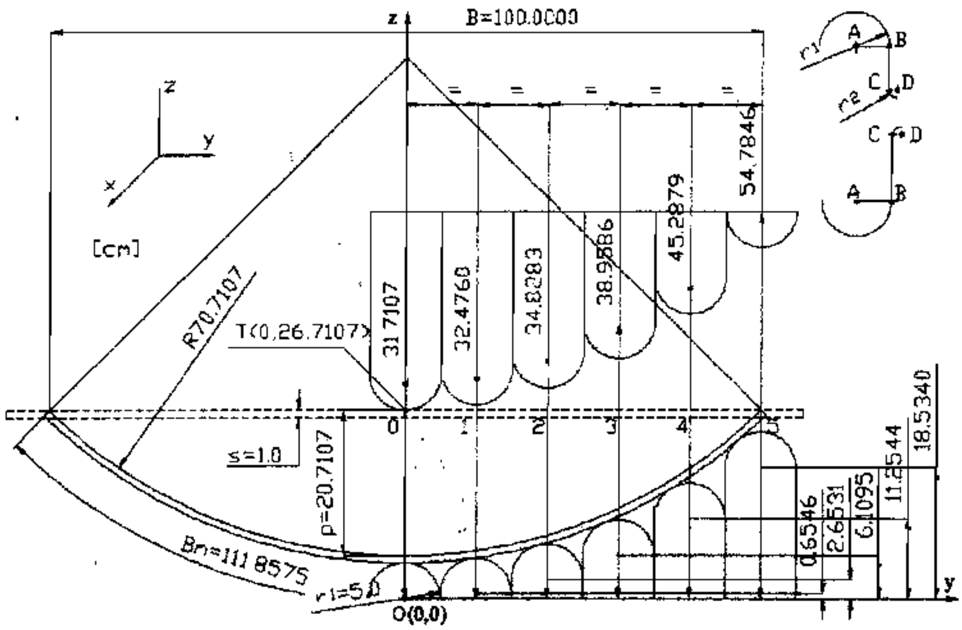


Fig.2 Cross section through die-plate-punch

**Table 1 Input and output data for PINCENTER simulated case**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Input data** | $R$ [mm] | 707.11 | | $r_1$ [mm] | 50 | $r_2$ [mm] | 0 |
| | $s$ [mm] | 10 | | $n$ | 5 | | |
| **Output data** | $B$ [mm] | 1000 | | $B_n$ [mm] | 1118,6 | $p$ [mm] | 207,11 |

| | Pin | | A | B | C | D | | Pin | | A | B | C | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Die** | 0 | x | 0 | 0 | 0 | 0 | **Punch** | 0 | x | 0 | 0 | 0 | 0 |
| | | y | 0 | 50 | 50 | 50 | | | y | 0 | 50 | 50 | 50 |
| | | z | 0 | 0 | 0 | 0 | | | z | 317.107 | 317.107 | 547.846 | 547.846 |
| | 1 | x | 0 | 0 | 0 | 0 | | 1 | x | 0 | 0 | 0 | 0 |
| | | y | 100 | 150 | 150 | 150 | | | y | 100 | 150 | 150 | 150 |
| | | z | 6.546 | 6.546 | 0 | 0 | | | z | 324.760 | 324.760 | 547.85 | 547.846 |
| | 2 | x | 0 | 0 | 0 | 0 | | 2 | x | 0 | 0 | 0 | 0 |
| | | y | 200 | 250 | 250 | 250 | | | y | 200 | 250 | 250 | 250 |
| | | z | 26.531 | 26.5308 | 0 | 0 | | | z | 348.283 | 348.283 | 547.846 | 547.846 |
| | 3 | x | 0 | 0 | 0 | 0 | | 3 | x | 0 | 0 | 0 | 0 |
| | | y | 300 | 350 | 350 | 350 | | | y | 300 | 350 | 350 | 350 |
| | | z | 61.095 | 61.0949 | 0 | 0 | | | z | 389.586 | 389.586 | 547.846 | 547.846 |
| | 4 | x | 0 | 0 | 0 | 0 | | 4 | x | 0 | 0 | 0 | 0 |
| | | y | 400 | 450 | 450 | 450 | | | y | 400 | 450 | 450 | 450 |
| | | z | 112.544 | 112.544 | 0 | 0 | | | z | 452.879 | 452.879 | 547.846 | 547.846 |
| | 5 | x | 0 | 0 | 0 | 0 | | 5 | x | 0 | 0 | 0 | 0 |
| | | y | 500 | 550 | 550 | 550 | | | y | 500 | 550 | 550 | 550 |
| | | z | 185.340 | 185.340 | 0 | 0 | | | z | 547.846 | 547.846 | 547.846 | 547.846 |

Finally, the die and punch meshing includes 70582 and 82308 finite elements, respectively, while the flat plate 400 finite elements.

For the continuous die-punch assembly modeling are necessary only the necessary radius of the desired shape and plate thickness. Thus, the die and punch meshing includes 2816 finite elements, while the flat plate 100 finite elements. In this case it wasn't necessary a fine meshing.

## 3. Numerical results

For both assembly configurations, the full geometrical models of the die-plate-punch assembly are shown in figure 3 and 4.

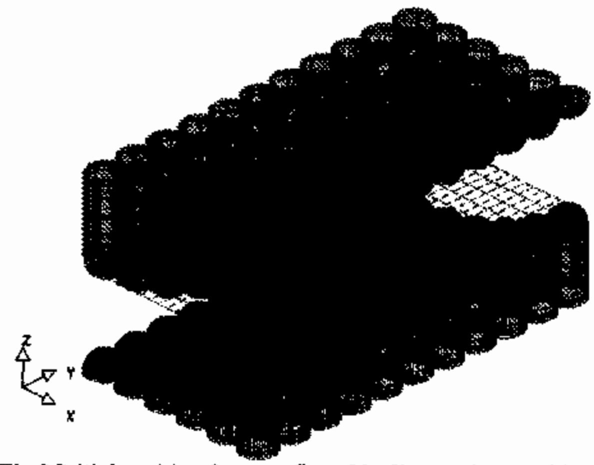

Fig.3 Initial position for reconfigurable die-punch assembly

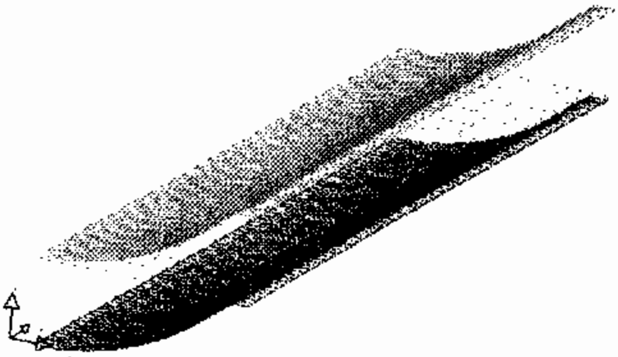

Fig.4 Continuous die-punch assembly in its initial position

At the end of the simulation process, the postprocessor features enable various interpretation of output data, mainly the 3D-deformed shape and its sections (Fig.5 and Fig.6) for comparison to the desired shape, as well as other results such as stress components, von Mises equivalent stress for each element at its Gauss integration points, the magnitude of the spring back, the time variation of the applied loading forces.

Fig.5 Plate shape before and after spring-back comparatively to desired shape (reconfigurable assembly)

Fig.6 Plate shape before and after spring-back comparatively to desired shape (continuous assembly)

On the basis to the coordinates of a points series obtained for a certain cross section (see Table 2 and Table 3), were drawn the plate shape before and after spring-back for each case comparatively to desired shape (Fig.7 and Fig.8).

**Table 2 Points coordinates for a cross section, before and after spring-back (case 1)**

| Before spring-back | | After spring-back | |
|---|---|---|---|
| *x* [mm] | *z* [mm] | *x* [mm] | *z* [mm] |
| 0 | 59.884 | 0 | 59.884 |
| 41.914 | 59.906 | 41.918 | 59.906 |
| 83.692 | 63.247 | 83.692 | 63.349 |
| 125.123 | 69.662 | 125.103 | 69.915 |
| 165.970 | 79.108 | 165.929 | 79.470 |
| 206.315 | 90.474 | 206.191 | 91.138 |
| 246.013 | 104.001 | 245.696 | 105.224 |
| 284.918 | 119.685 | 284.353 | 121.518 |
| 323.002 | 137.258 | 322.177 | 139.640 |
| 359.662 | 157.645 | 358.615 | 160.424 |
| 395.192 | 179.929 | 394.065 | 182.842 |
| 429.479 | 204.089 | 428.908 | 206.773 |
| 462.241 | 230.273 | 461.839 | 232.194 |
| 484.198 | 247.573 | 484.242 | 248.885 |
| 506.155 | 264.891 | 506.673 | 265.547 |

**Table 3 Points coordinates for a cross section, before and after spring-back (case 2)**

| Before spring-back | | After spring-back | |
|---|---|---|---|
| *x* [mm] | *z* [mm] | *x* [mm] | *z* [mm] |
| 0 | - 4.923 | 0 | -5.38 |
| 55.476 | - 2.597 | 55.143 | -2.298 |
| 110.556 | 4.271 | 110.312 | 5.861 |
| 164.972 | 15.402 | 164.390 | 18.397 |
| 218.313 | 30.012 | 217.563 | 34.284 |
| 270.331 | 49.142 | 269.696 | 53.422 |
| 320.703 | 72.456 | 320.704 | 75.333 |
| 369.394 | 100.042 | 370.508 | 99.880 |
| 392.851 | 114.880 | 394.773 | 113.319 |
| 415.525 | 130.318 | 418.365 | 127.942 |
| 437.511 | 147.105 | 441.411 | 143.348 |
| 458.442 | 164.105 | 463.664 | 159.936 |
| 478.978 | 181.742 | 485.678 | 176.637 |
| 500.766 | 202.214 | 504.423 | 191.720 |

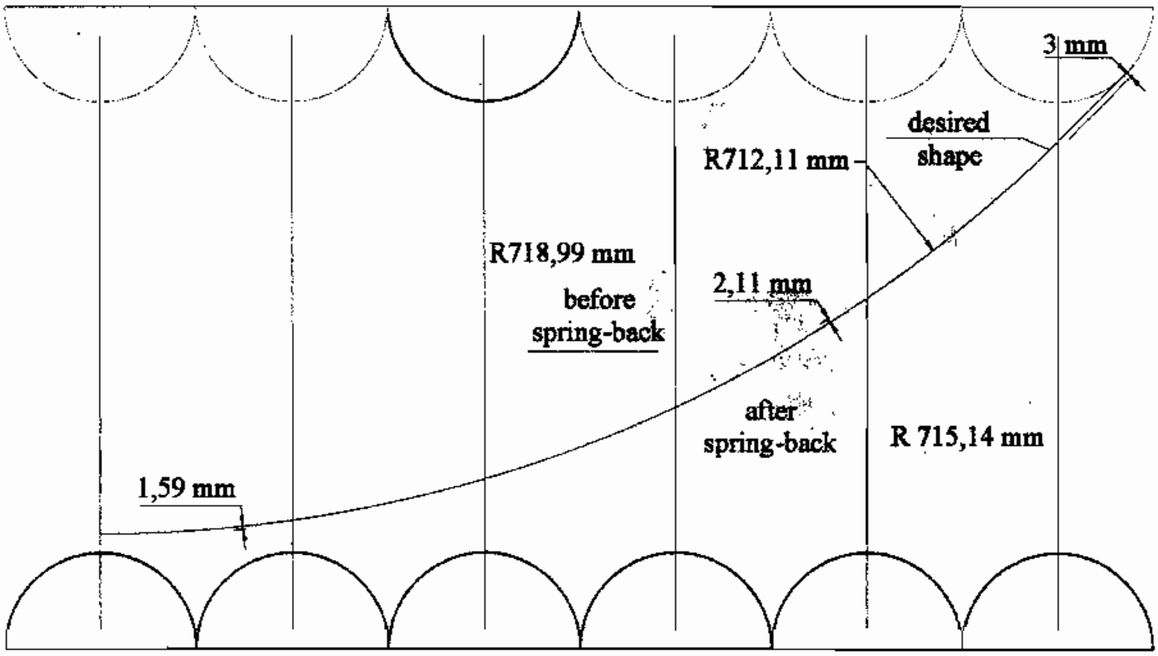


Fig.7 Plate shape before and after spring-back comparatively to desired shape (case 1)

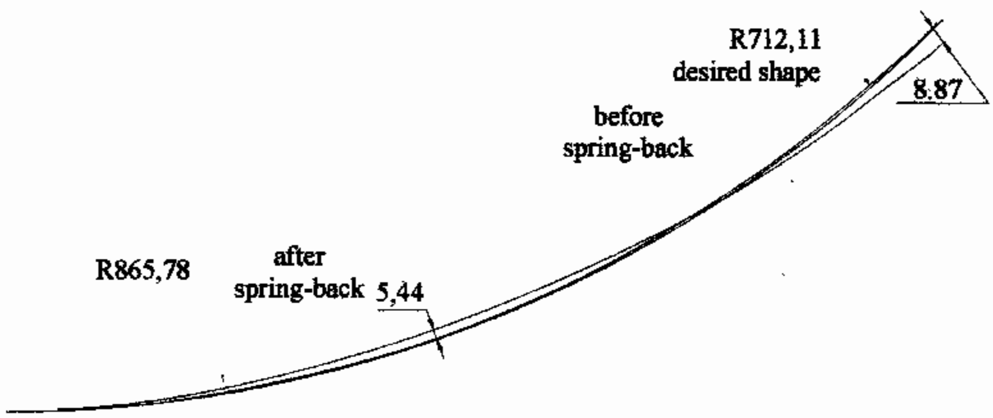


Fig.8 Plate shape before and after spring-back comparatively to desired shape (case 2)

## 4. Conclusions

The present study conclusions are as fallows:

- The obtained surface shape using continuous die-punch tool is better qualitative than those obtained with reconfigurable die-punch assembly with forming pins.
- The spring back is greater when press forming is simulated with continuous die-punch tool. In this case, it is necessary to recalculate the initial tool radius in concordance with spring back value.

The results of press forming simulation of the large-sized cylindrical plates with special equipments based on the "discrete die-punch" reconfigurable tooling concept proved possibility to explore and evaluate easily different series of surface configurations that leads to the desired curved shape.

## 5. References

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## STUDIU COMPARATIV PRIVIND FASONAREA TABLELOR CU SIMPLA CURBURĂ CU ANSAMBLU MATRIŢĂ POANSON CONTINU ŞI RECONFIGURABIL

Rezumat

In această lucrare se propune o soluţie alternativă la fasonarea tablelor prin presare. De fapt metoda tradiţională este înlocuită cu un ansamblu special matriţă poanson bazată pe conceptul de matriţă cu suprafeţe discrete. Acest studiu numeric comparativ este aplicat la tablele cu simplă curbură şi este realizat cu programul LS-DYNA, modulul DYNAFORM. Pentru a analiza procesul elasto-plastic cu neliniarităţi geometrice complexe s-a ales elementul tip placă şi membrană Belytschko-Lin-Tsay. Modelarea geometrică a ansamblului matriţă poanson reconfigurabil necesită calcularea coordonatelor caracteristice ale profilului suprafeţelor de lucru, în timp ce pentru modelarea procesului tradiţional de presare sunt necesare doar razele matriţei şi poansonului şi grosimea tablei. O serie de concluzii au fost obţinute din simularea numerică a procesului de presare atât pentru cazul utilizării matriţelor tradiţionale continui cât şi în cazul utilizării matriţelor reconfigurabile.

## VERGLEICHBARE STUDIE FÜR DIE EINZELN-GEBOGENEN PLATTEN, DIE MIT UNUNTERBROCHENEM UND STERBEN-DURCHSCHLAG RECONFIGURABLE SICH BILDEN

Zusammenfassung

In diesem Papier wird eine Ausweichlösung zur herkömmlichen Presseformung der Platten vorgeschlagen. Tatsächlich wird das traditionelle ununterbrochene Sterbendurchschlag Werkzeug mit einem besonders Sterben durchschlag ersetzt, der auf dem "getrennter Sterbendurchschlag" reconfigurable Werkzeugausstattungkonzept basiert. Diese vergleichbare numerische Studie wird auf eine einzeln-gebogene Platte zugetroffen und wird mit weichem LS-DYNA FEM, Dyna-Form Modul gebildet. Das Belytschko-Lin-Tsay Oberteilelement, das auf einer kombinierten Corotations- und Geschwindigkeit-Belastung Formulierung basierte, wurde beschlossen, um den elastoplastischen Prozeß mit komplizierter geometrischer Nichtlinearität zu analysieren. Das geometrische Modellieren der reconfigurable Sterbendurchschlag Versammlung Antragberechnungen für die charakteristischen Profilkoordinaten der Funktion Oberflächen, während für das ununterbrochenes Sterbendurchschlag Modellieren nur der notwendige Radius der gewünschten Form- und Plattenstärke notwendig sind. Eine Reihe Zusammenfassungen, die von der numerischen Simulation der Presse bildet Prozeß für ein zylinderförmiges Platte Formverwenden ununterbrochen, beziehungsweise reconfigurable Sterbendurchschlag Werkzeug erreicht werden, werden am Ende gezeigt.