# Computer Simulated and Experimental Verification of Tooling for Progressive Deep Drawing.

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## Abstract

*The ability to predict different process conditions in deep drawing is essential for die face designers, tooling, stamping and manufacturing engineers. These predictions in turn affect the speed, accuracy and cost of the final produced product. This paper briefly discusses the possibilities of controlling the blankholder pressure distribution and shows some computer simulations done in DYNAFORM, with the results being experimentally verified with tooling designed by the authors.*

## Introduction

Drawing different and difficult sheet metal parts usually produce undesired wrinkling and even tearing of our wanted component before completion of the deep drawing operation. In order to help eliminate this undesired effect, the blank holder pressure should be controlled. One way to control the blank holder pressure is to have a single action draw cushion that can be CNC-controlled with a hydraulic cylinder and height-adjustable cushion pins. Each cushion pin should be also CNC-controllable in height where the force transmitted through the blank holder can be measured by a series of load cells. In this way it is possible to control the material flow for producing pressings in high tensile steels. Examples can be seen in the drawing of one-step automotive fuel tanks, dual-phase steels and tailored blanks.

## Computer Simulation

In engineering design one of the most important tasks is to be able to predict the consequences of chosen approaches at early design stages. Engineers who work with product design and development know the importance of understanding the complete process from conceptual design to the final planed production. Computer simulations help the mechanical engineer to better understand the product or process and make corresponding improvements with fairly high accuracy. Nowadays more or less every product is simulated, from a complete system to individual components.

The computer simulation of blank holder force control is of no exception, with today's evolving simulation software technology we are able to simulate the deep drawing process and adjust the blank holder force at any given point on the blank holder with very high accuracy and with very little effort as can be seen from the figures. A model, which has been constructed and simulated, is shown on figure 1, we took into consideration the computer simulation of a blank holder that is to produce a cylindrical component. This model was simulated in DYNAFORM-PC version 2.1.

The DYNAFORM-PC software package consists of four programs. These programs represent the pre-processor, solver and post-processor. They are DYNAFORM, LS-DYNA, eta/PostGL and eta/Graph. DYNAFORM is the pre-processor portion of this software package. Sheet metal forming models are constructed using this software, which include VDA and IGES translators for importing line data and a complete array of tools for altering or constructing line data and as well as meshing it. LS-DYNA is the software package's solver. DYNAFORM has a complete LS-DYNA interface allowing the user to run LS-DYNA from DYNAFORM. The eta/PostGL and eta/Graph are the post-processing portions of this package. These programs are used to post-process LS-DYNA result files from the analysis. eta/PostGL creates contour, deformation, FLD, and stress plots as well as animations with the result files. eta/Graph contains functions for graphically interpreting the same results.

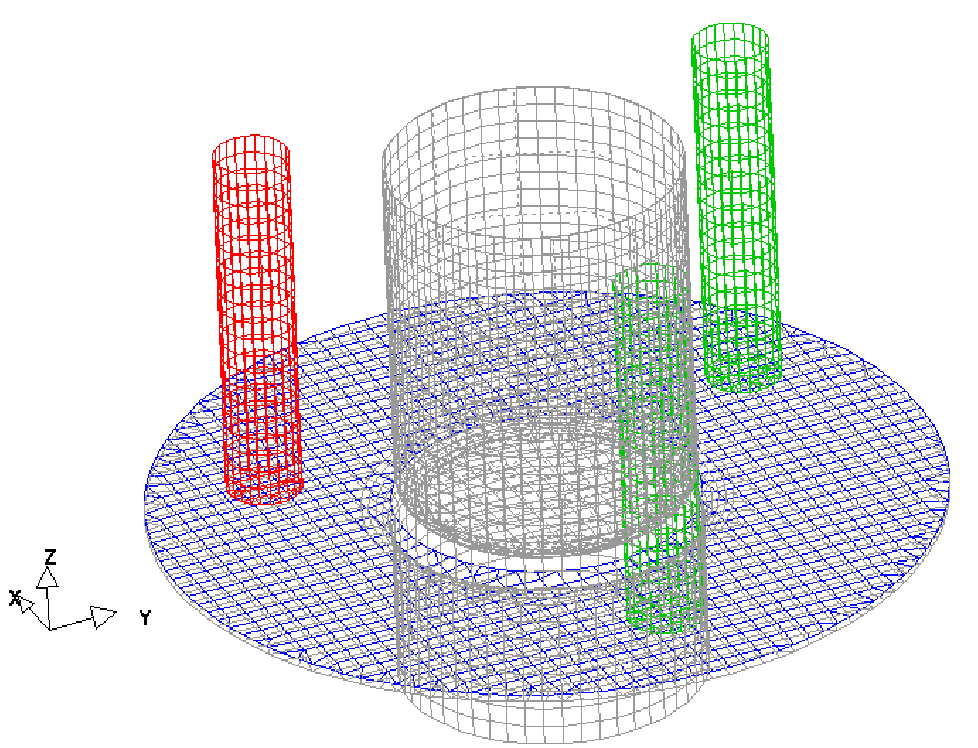


Figure 1: Tooling used to simulate non-uniform blank holder pressures. The green transfer pins have constant force and the red transfer pin has a slightly higher force acting on the blue elastic-plastic with linear strain hardening blank holder.

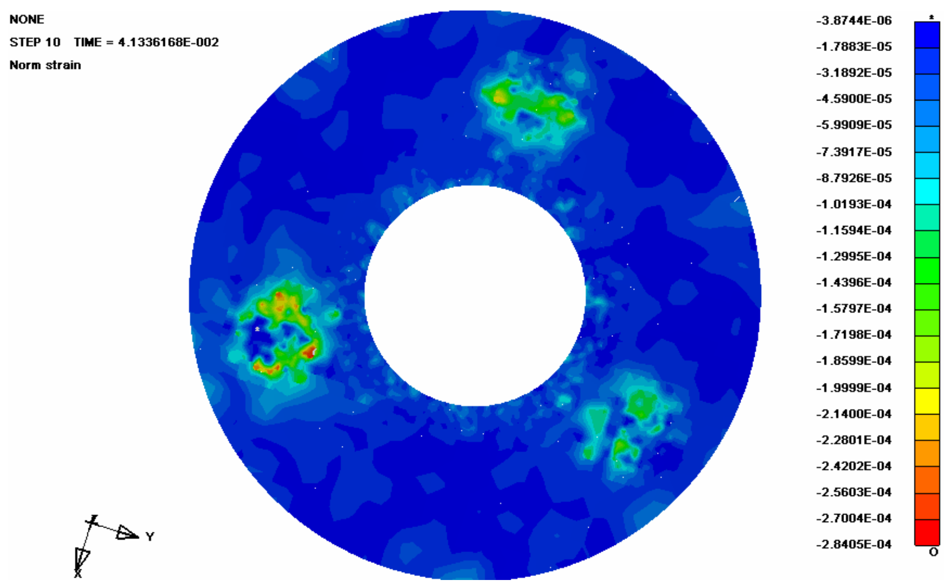


Figure 2: Computer Simulation of Non-uniform Blank holder pressure

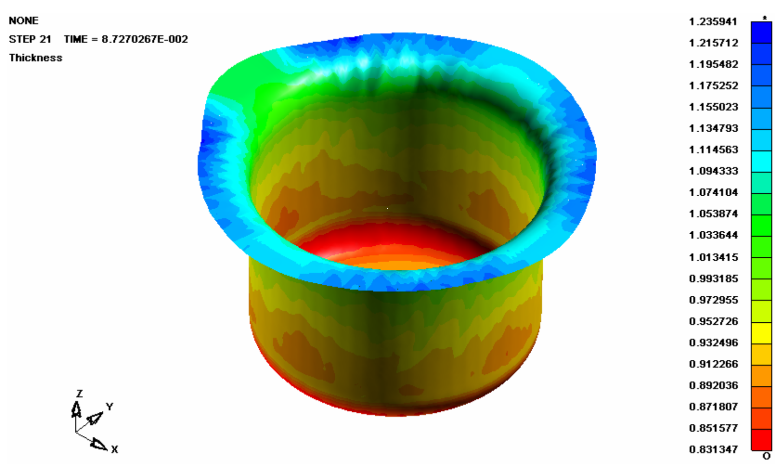


Figure 3: Resulting cup from Computer Simulations

As we can see from the figures, it is possible to simulate the deep drawing process with varying blank holder forces at different points on the blank holder. But to be able to experimentally verify this computer simulation a tooling must be designed with a series of load cells that transmit the forces at various cushion pin locations.

## Experimental Tooling

Deep drawing tooling was developed at the department of Material Science & Technologies, at the Faculty of Mechanical Engineering, STU in Bratislava. The punch diameter was 79 mm. The die is intended for use in a single action press with a draw cushion. For this reason the blank holder force is applied using three transfer pins. Each pin is height adjustable and equipped with a load cell that transmits the force acting on the pin. The transfer pins are connected to the blank holder via threaded connectors. As well with the ability to measure the blank holder forces, we designed our tooling to also measure the die force present as well as the punch force and stroke distance. The actual realized experimental tooling can be seen on figure 4. In our model, the forming force is exerted by the slide above through the die and the blank holder onto the cushion in the press bed. The draw punch and the blank holder of the drawing tool are both located in the base plate on the press bed. The transfer pressure pins, which come up through the press bed and the base plate, transfer the blank holder force from the draw cushion onto the blank holder. The female die and the ejector are mounted on the press slide. At the start of the forming process the blank is held under non-uniform pressure between the draw die and the blank holder. The slide of the press pushes the blank holder downward over the draw die – against the upward-acting force of the draw cushion. The part is formed via the downward movement of the die over the stationary draw punch. The press slide must apply both the pressing and the blank holder forces. As mentioned previously, three load cells will be used for measuring the blank holder and three will be used to measure the die force as per figure 4. The design of the die and blank holder force-measuring device is according to figure 5.

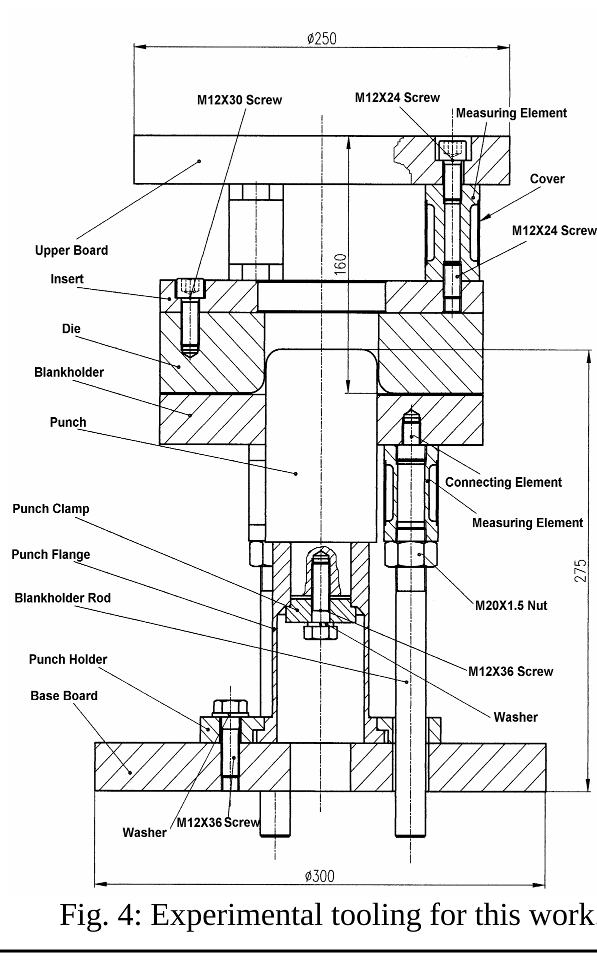


Fig. 4: Experimental tooling for this work.

These load cells have three HBM 6/120LY11 tensometric sensors glued onto them in the transverse and longitudinal direction. They are connected into a half bridge series with two compensating resistors at 120 Ω to even the bridge. The connection can be seen in figure 6. The measuring elements were quenched and tempered to yield a hardness of 46-52 HRC, in order to increase their strength.

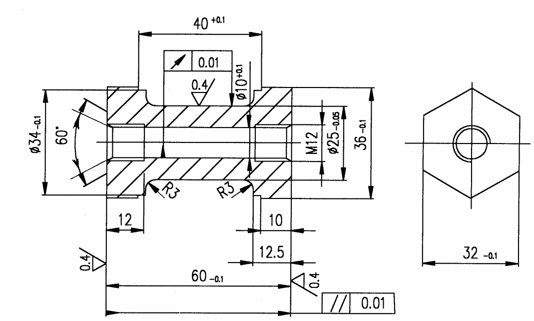

Figure 5: Design of force measuring device.

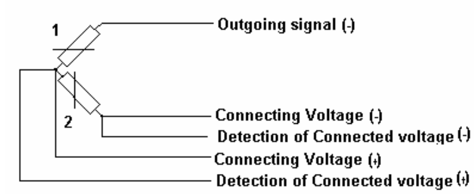


Figure 6: Half-bridge connection of our die and blankholder force cells, (1) Measuring bridge, and (2) compensating bridge.

In order to measure the punch force we also have three HBM 6/120LY11 tensometric sensors glued onto the punch in the transverse and longitudinal direction. The only difference is that it is connected in a Full-bridge connection (see figure 7). It must be noted that the stroke-measuring device was also connected as a full-bridge connection.

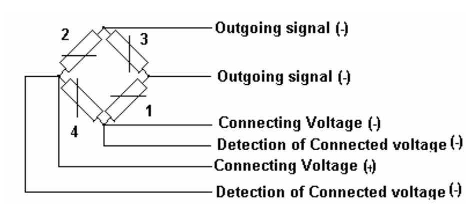


Figure 7: Full-bridge connection of our punch force cells, (1), (2) Measuring bridge, and (3), (4) compensating bridge.

The force cells that were described measure the change in mV/V. In order to convert the signal into force readings of KN and a stroke reading of mm, the CONMES – Spider 12 with applicable software was used. The Conmes – Spider program is generally used in laboratory atmospheres or in educational institutions. The program and hardware allows us to convert voltage into useful units for the purpose of measurements. The hardware is connected via the LPT1 port located on the back of our laptop.

## Results

First of all we took into account three transfer pins from our tooling in different areas of the blank holder, two of the transfer pins exerted equal forces, while the third exerted a much higher force. After computer simulation of the transfer pins, we tried to repeat the operation experimentally to verify the computer simulation results. The results of computer simulations and experimental verification can be seen in figure 8. We can see that from our results we can simulate different blank holder pressures quite accurately as figure 8 shows, this in turn allows us to simulate and control the deep drawing process.

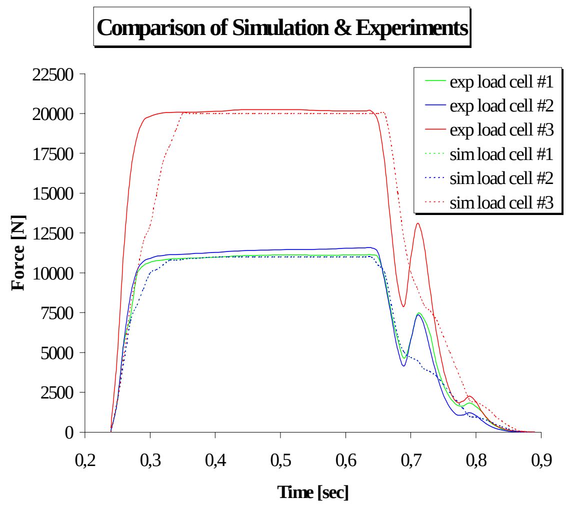


Figure 8: Experimental Verification of Computer Simulations

The following figures show the computer simulation and experimental verification of the 170 mm initial blank. Note the similarities between the computer simulations and experiments.

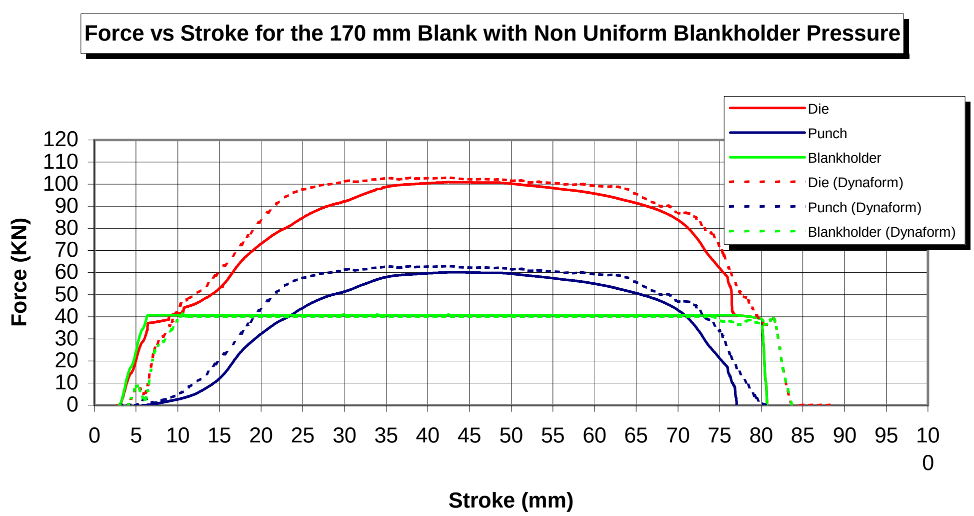


Figure 9: Comparison of simulated and experimental force results of a drawing from an initial 170 mm blank.

Figure 10: Simulation vs. Experimental Verification.

The above figures impressively show the simulated and experimental anisotropic properties of our material. This is in the form of ears and dips located at the edges of the cup after the drawing process. They also show the effect of non-uniform blank holder pressure on the drawings in the form of an elongated ear on one side of the cup.

## Conclusions

From the above results it can be stressed that for multi point cushion systems, special tool concepts are necessary, to control the pressure between blank holder and draw ring and in this way we can also control the material flow. A modification of the pin forces have to result in a corresponding modification of the pressure between blank holder and draw ring in a determined segment of the die. For this a new tool concept for multi point cushion systems has been developed. Using it, the working range between wrinkles and tears can be increased enormously. So, the forming process gets more robust and more complex parts can be manufactured.

### References

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