

IMPROVED PART QUALITY IN COMPLEX DEEP DRAWING USING VARIABLE DRAW BEAD MOTION CONTROL

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ABSTRACT

The use of locally varying draw bead motion to remove complex deep drawn part defects and improve formability has been extensively studied in the academic research community over the last twenty years. The new idea of using variable draw bead motion is conceptually simple: if wrinkle is starting to form, the draw bead penetration is increased thus relatively quick (typically 0,5-0,8 sec.).

The present papers describe a FE analysis of the effect that different variations of the draw bead position have on the rate σ_{22}/σ_{11} , considered a criterion for wrinkles developing process. The stress σ_{11} and σ_{22} , represent Cauchy stress tensor components, which usually are a tension, respectively compression stress in one of critical zones of the part. When this rate is higher than his limit value, the compression stress is dominant and the wrinkles appear. The motion of the draw bead can control the flow of the material in die cavity and improve quality of the part. An optimal motion of draw bead is obtained using FE analysis.

KEYWORDS: draw bead motion control, deep drawn part quality, finite element modelling

1. Context (Motivation)

Sheet metal forming is one of the primary manufacturing processes which have been a modern development. The deep drawn process produces high-strength, lightweight parts more cost-effectively than other methods. Among the advantages offered by deep draw are: rapid press cycle times, fewer operations required to finish a part, the ability to create complex geometries unattainable through other processes. The control of flow of material into the die cavity is crucial to good part quality and consistency. Different solutions are developed in this field during the time but all this techniques assure the control of the forming process by geometrical criteria and those can be applied for particular shape of the parts. During the time many numerical and experimental techniques have been incorporated in die try-out procedure in order to improve time and production costs. Different devices and mathematical models are proposed to identify solutions to reduce springback and to determine the effect of draw beads in order to

optimize here utilization. (Sanchez L.R., 2000; Y.T. Keum, B.Y. Ghoo, J.H. Kim, 2001; Li Shuhui, Zhongqin Lin, Weili Xu Bao Youxia, 2002; L.M. Smith ,Y.J. Zhou, D.J. Zhou, C. Du, C.Wanintrudal, 2009, Maier 1997).

It result that draw beads represent an important element in deep drawing process to control the flow of the material in die cavity and material stability. At the passing through the draw beads, the material suffers progressively cycles of deformation, type bending and stretching/unbending and stretching. Consequently, the material effect supporting deformation with draw beads is a residual strength and bending moment inverse proportional with the centreline curvature of the sheet, respectively with his square.

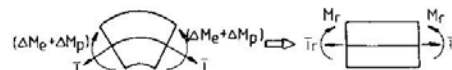


Fig.1. Effects of a single bending/unbending under tension cycle [Maier 1997]

Considering these effects, in the design phase of the sheet metal forming process, we can decide the geometry and penetration of the draw beads but during the process many uncontrolled stress state can appear during deep drawing process determining the sheet instability. The characteristic stress states during deep drawing process are (figure 2):

- stress state 1 – tension+compression with compression dominance determining wrinkles during the process;
- stress state 2 – tension+compression with tension dominance, determining wrinkles after the process by springback;
- stress state 3 – biaxial tension when tearing appears.

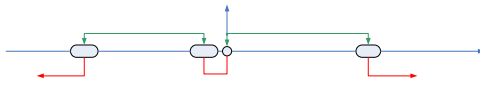


Fig. 2. Characteristic stress states during deep drawing process

The control of draw beads motion represent a solution to change and control these instabilities and many researcher's studies propose different devices and mathematical models to determine the effect of draw beads and optimize its utilization.

Between these a recent technology [Papaioanu 2010] - SCS (Short-Cycle-Stretch forming) - is proposed combining a plane pre-stretching and subsequent deep drawing operation for production of small car body panels with high demands concerning surface quality. This technology is based on a low cost tool design including two opposed bead sets for an alternate bending and unbending of the sheet metal boundary.

During the first step of the process the blank become stretched laterally by the bead sets with three upper and three lower bead elements. The second step is the deep drawing operation starting with the first contact of the punch with the pre-stretched blank. By variation of the shoulder radius of both bead sets and the blank dimension it is possible to reach a predefined strain level during the process.

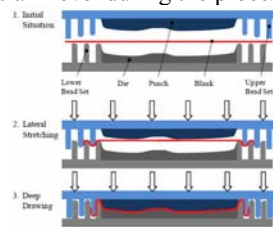


Fig. 3. Schematic view of the drawing process by SCS Tool [Papaioanu 2010]

The next step of researches, conducted by Papaioanu & all., was the utilization of additional

bead elements were located in transversal direction in order to gain higher restraining force in minor strain direction. However, wrinkles and cracks results in the corner region of the drawn part. In order to improve the process and part quality a further development step was conducted so that no wrinkles and crack occur during forming process. In this case, the existing transversal bead set has removed and substituted by a chamfer tool including a conventional draw bead acting five millimetres before process ends and a flexible element for self-adjusting the drawing clearance between die and punch during the process.

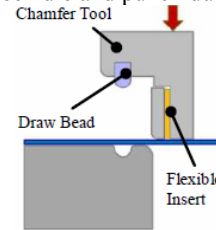


Fig. 4. Adjustable tool setup for compensation of sheet thickness fluctuation [Papaioanu 2010]

All this optimization solutions offer the possibility to obtain good quality for relative simple shapes of car body panels without large uncontrollable deformed surfaces during the process. Additional to this limitation, die try-out procedure offers only open-loop solutions for process control and new control procedures and process design solutions are required.

Experimentally, different kinds of blank holder trajectories have been used to study their effects on produced part quality.

The present paper present a finite element study of the effect of different proposed draw beads trajectories on the part quality and consistency.

2. Numerical model presentation

The finite element analysis is performed using MARC Mentat software. Numerical model of the proposed deformation schema, presented in figure 5, represent a reduced order model of deep drawing process with draw beads.

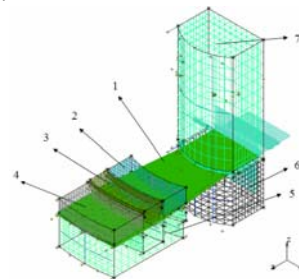


Fig. 5. Reduced order model of complex deep drawing process with draw beads [Maier 2011]

1 -specimen; 2 – blank holder1; 3 – draw bead; 4 – blank holder2; 5 - die; 6 – counterpunch; 7 – punch. We consider rigid bodies: die, counterpunch, punch, drawbead, blank holder1 and 2. The specimen is considered deformable body and his geometry is presented in figure 6.

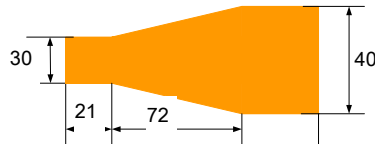


Fig. 6. Specimen geometry [Maier 2011]

Boundary conditions – Only one boundary condition is imposed consisting in blocked displacements on x and y directions for all right side specimen nodes and imposed same displacement on Oz axe direction like the punch and counterpunch. This boundary condition results from the experimental situation when the specimen is stretched between the punch and counterpunch in order to have the same displacement on the z direction. Its definition is performed in the BOUNDARY CONDITION menu of MARC Mentat software.



Fig. 7. Boundary conditions

The considered material for finite element analysis is dual phases steel DP600 with 1 mm thickness. *Material behaviour* is described by Swift law, as:

$$\sigma = A(\epsilon_0 + \bar{\epsilon}^p)^m \quad (1)$$

Material coefficients and mechanical characteristics are defined by following values: A=1093, m=0,187, E=210 000 MPa, $\nu = 0,33$.

Friction law considered is Coulomb law with 0,01 friction coefficient.

We have considered the following evolutions of the draw bead position (figura 8):

- successive action of the draw bead (penetration up to a predefined value and maintain this position until the end of the process) and of the

- punch (whose action starts when reaching preset value the depth of draw bead penetration);
- simultaneous action of the draw bead and punch with consideration of the various evolutions of draw bead position.

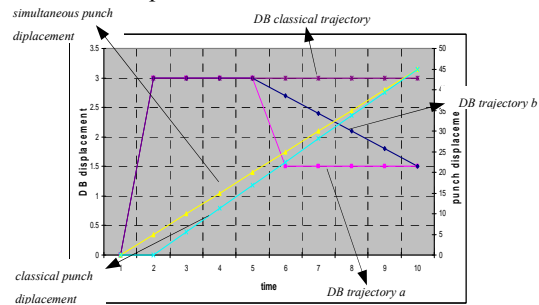


Fig.8. Different trajectories of draw bead and punch

3. Results and conclusions

Numerical simulation results shows a differential evolution of the ratio $\frac{\sigma_{22}}{\sigma_{11}}$ during forming process, depending on the type of action (simultaneous or successive) of the draw bead and its motion trajectory (Figure 9)

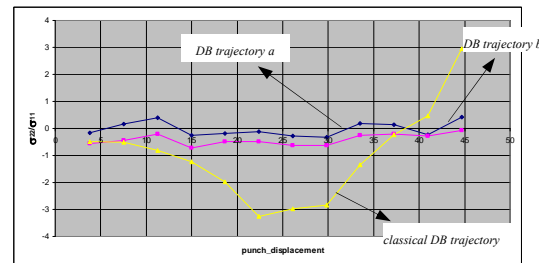


Fig. 9. Stress rate evolution during the process, function on draw bead trajectory

From their analysis resulted that in classic case, used so far in metal forming processes while the draw bead enters into the material before the punch displacement starts and remains in this position until the end of the process, there is a substantial critical values exceeding 1.5 of the stress ratio that vary in this case between 2.94742 and -3.26625.

In contrast, when simultaneous action of the punch and draw bead and gradual withdrawal after 50% of the active trajectory of the punch, the stress ratio is between -0.23 and 0.39 in the case of *DB trajectory a* and between -0.22 and -0.72, if the *DB trajectory b* case is considered. Because the *DB trajectory a* determinate the stress state 2 that can determinate wrinkles formation after metal forming process (caused by elastic recovery), it follows that the draw bead optimal motion trajectory is *b* which

meet the limit criteria V1, V2 and V3 and also offers a reserve to the stress ratio variation before the loss of material stability.

We demonstrate that among various possible evolution of draw bead position during deep drawing process, we can determine one to meet the limit criteria V1, V2 and V3 and is considered the optimal reference motion trajectory.

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Îmbunătățirea calității procesului de ambutisare a pieselor complexe prin controlul deplasării nervurii de reținere

- Rezumat -

Utilizarea unei variații a poziției nervurii de reținere pentru diminuarea defectelor pieselor complexe ambutisate și îmbunătățirea deformabilității materialelor a fost mult studiată în ultimii douăzeci de ani de către cercetătorii din mediul academic. Ideea de utilizare a unei variații a poziției nervurii de reținere pe parcursul desfășurării procesului de ambutisare este simplă: dacă formarea cutelor debutează, adâncimea de pătrundere a nervurii de reținere va fi mărită într-un timp relativ scăzut (0,5-0,8 sec.).

Lucrarea de față descrie analiza cu EF a efectului diferitelor moduri de variație a poziției nervurii de reținere asupra raportului σ_{22}/σ_{11} , considerat drept criteriu pentru procesul de dezvoltare a cutelor. Tensiunile σ_{11} și σ_{22} reprezintă componente ale tensorului Cauchy al tensiunilor care, uzual, sunt o tensiune de întindere, respectiv de compresiune într-o zonă critică a piesei. Când acest raport este mai mare decât o valoare limită, tensiunea de compresiune este dominantă și apar culele. Deplasarea nervurii de reținere poate controla curgerea materialului în cavitatea plăcii de ambutisare și îmbunătăți astfel calitatea piesei. O evoluție optimă a poziției nervurii de reținere, pe parcursul desfășurării procesului de ambutisare, este determinată utilizând analiza cu EF.