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THE INFLUENCE OF SHEET THICKNESS ON DRAWBEAD RESTRAINING FORCE IN SHEET METAL FORMING

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Abstract. *Drawbeads are very important to control the material flow into the die cavity in sheet metal forming, although excessive deformations may occur when the sheet passes between them. There are some disadvantages in their employment, such as difficulties of adjustment during die try-outs for obtaining the actual Drawbead Restraining Force (DBRF). To reduce the number of try-outs, which are very time consuming, precise drawbead concepts are necessary to solve these problems and to control the sheet flow into the die cavity efficiently. The aim of this paper, part of a wider study about drawbeads, is to understand the influence on the DBRF of two of their main design characteristics, namely, the sheet thickness and the friction coeffcient. For this purpose simulations with Finite Element models were designed by varying the sheet thickness and maintaining constant the other geometric and material parameters.The results were compared with experimental databases. Two different materials were used: A-K Steel and 2036-T4 Aluminum, in order to establish a pre-estimate DBRF theory for these cases.*

Keywords*: Drawbead, restraining force, finite element method, sheet metal forming*

1. Introduction

Control of the quantity of material in expansion in the central and external areas of the piece subjected to the stamping process is very important. The force exerted by the binder on the sheet metal supplies a restraining force that controls the metal flow. However, in some applications the friction by itself is not able to adequately control the material flow through the blankholder. In these situations drawbeads are employed and act in association with the blankholders to efficiently control the flow of metal into the die. This flow depends on the drawbead restraining force (DBRF), which must be sufficient to avoid defects such as wrinkles and fractures, in the piece being stamped.

The drawbead used in the present research consists of a semi-cylindrical bead on one binder face that fits into a groove on the opposing binder face, generally on the edges of the die. See details in Fig. 1:

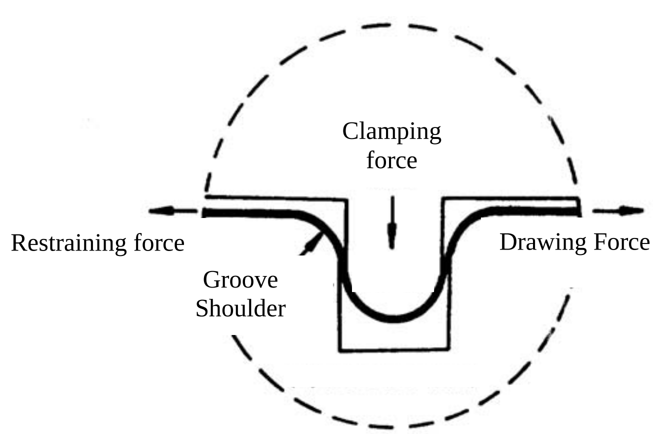

Figure1: Drawbead stamping process.

These devices are very important to effectively control the material flow into the die cavity during the sheet metal forming process. However, excessive deformation may occur when the sheet passes between them, as shown in recent research (Ghoo and Keum, 2000). There are other disadvantages of drawbead employment including difficulties in the adjustment of die try-outs for obtaining the ideal Drawbead Restraining Force (DBRF). Another problem that arises when these devices are used is the difficulty in determining the magnitude of the DBRF for different geometrical forms and material properties. For this reason precise drawbead measurements constitute a significant research objective.

In order to study drawbeads, research has been conducted using numerical models, (Ghoo and Keum, 2000; Carleer and Menders, 1996). Other research has been developed to identify an analytical model that would be able to predict the DBRF for most geometrical forms, (Chen and Tszeng, 1998; Kim and Kim, 1991; Courvoisier, Martiny and Ferron, 2003 and Stoughton, 1988).

The present research is part of a wider study concerning drawbeads. The aim is to examine the contribution of the most important variables in the determination of the DBRF. However, only the results of the influence of sheet thickness will be considered. Empirical equations to predict circular transversal section DBRFs will be sought for the most common commercial sheet thickness used in the stamping process.

Experiments have been designed (Nine, 1978 and Nine, 1982) aiming to investigate stamping variables affecting the DBRF when a circular drawbead is employed in a binder-holding process. These data were used to validate the current research.

2. Principal parameters

A complex combination of geometrical and material factors arises from the deformation forces. One factor, which affects the value of these forces, is the magnitude of the local strain, (Nine, 1978). This is determined by the geometry of the drawbeads and the thickness of the sheet metal. See Figure 2.

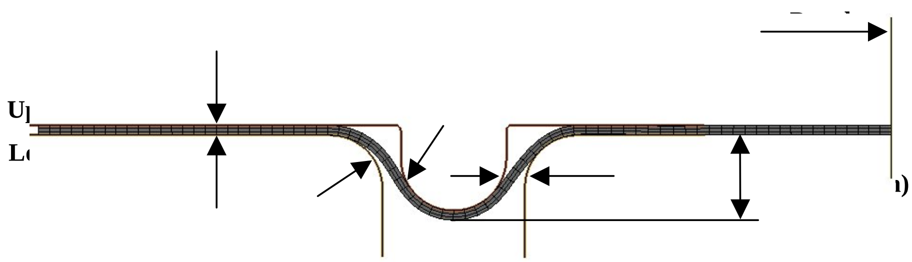

Figure 2. Circular drawbead geometry

Clearance between the blankholder and the drawbeads has an important influence on the observed radii. If the observed radii are greater than those used in the reference shape, the bending strain will be less than calculated. It must be remembered that the magnitude of plastic strain compared with elastic strain will determine the plasticity assumption.

The deformation forces are affected by strain hardening, which is represented by a constitutive equation. When a sheet is subjected to the force of the drawbead, its deformation is very complex because the bending of the sheet is inverted four times at punching. Tensile and compressive strains occur, at the same time, on both sides of the sheet, varying from zero at the neutral axis, to maximum values on the sheet surface. Cyclical strain is considerably different from unidirectional increasing strain hardening (Landgraf, 1969). Formulating the appropriate equation for this case may be difficult.

Finally, the state of the strain may influence the strain hardening. Two models in Finite Elements have been designed to compare their results with those obtained from experimental data in order to verify the importance of these parameters.

3. Finite element models

Aiming to calculate the most effective DBRF, two different FE models were designed. In the first one, as shown in Fig. 3, a sheet is subjected to a circular drawbead between the upper binder and the die. Its mesh is structured with quadrilateral elements having three elements along the sheet thickness. Seven different sheet thicknesses were simulated.

The Figure demonstrates the blank holding force (BHF) direction, the punch stroke direction and the bead that fits into the die groove.

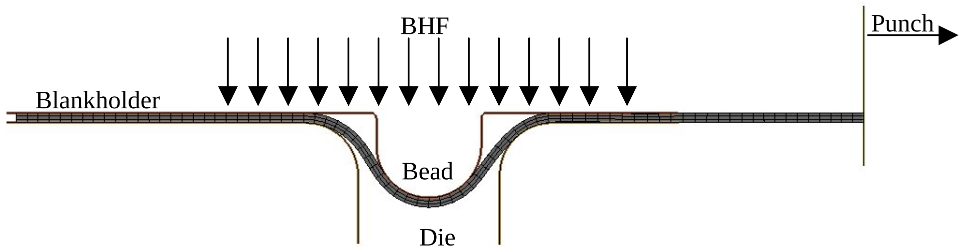

Figure 3. Suitable mesh of Model 1 with circular drawbead

The second one was designed similarly to Model 1, but without the drawbead, as shown in Fig. 4. The aim was to calculate only the contribution of the drawbead to the DBRF, neglecting the contributions of friction along the whole of its extension. This contribution was simulated in Model 2 and, subsequently, subtracted from the DBRF calculated in Model 1, with a drawbead.

Figure 4. Suitable mesh of Model 2 without a drawbead

By analyzing the path of a sheet element it was possible to verify the minimum punch stroke necessary to simulate the complete process of bending, sliding and unbending the sheet.

4. Parameters and methodology

Table 1 shows the principal values of the parameters used in several simulations and the material behavior laws adopted:

Table 1. Assumptions of material properties and material behavior laws.

Material	2036-T4 Aluminum	A-K Steel
Young's Modulus (MPa)	70.5	206
Poisson's ratio (ν)	0.34	0.29
Conventional elastic limit (MPa)	182	171.7
r_0 (Lankford coefficient)	0.894	1.58
r_{45} (Lankford coefficient)	0.611	1.58
r_{90} (Lankford coefficient)	0.660	1.58
Hill (Equivalent stress)	Hill 90	Hill 48
Anisotropy	Anisotropy	Transversal Anisotropy
Hardening law	Isotropic-Nadai	Isotropic-Nadai
Isotropic hardening constant (MPa)	540	516
Isotropic hardening exponent	0.225	0.230
Hill exponent	1.72	1.72

The simulations were made using seven different sheet thicknesses: .55, .65, .76, .90, 1.10, 1.30 and 1.50 millimeters. The total sheet length was 80 mm. A sheet thickness of .76 mm was used to validate the results with the experimental data, (Nine, 1982). Moreover, the following described parameters were adopted with equal values to those from the experimental data.

After validation procedures, by try-outs, the magnitude of the BHF was obtained. This calculation included examination of the upper bead fitting perfectly, without clearances from the die, for both materials. The value obtained was equal to 25 KN.

A vertical clearance, *c*, was assumed and kept equal to .76 mm, during all simulations. See Fig. 2.

The bead penetration into the die, *h*, in every case, was maintained equal to 7.7 mm. The friction coefficient was assumed equal to .17.

The shoulders, the bead and the die radius were designed with values equal to 4.75 mm.

The simulated values for stroke and velocity of the punch were 38 mm and 85 mm/s, respectively. This punch stroke was carefully calculated in order to ensure that a sheet element would pass along the full extension of the drawbead.

4. Results

To conduct the simulations, the Finite Element (FE) software used was STAMPACK®. The mesh was designed as described in Section 3. The adjusting parameters used in the software are described in the previous section.

4.1. The influence of sheet thickness on DBRF

Figure 5 illustrates one of the results obtained directly from the DBRF simulations using FE. This result is for an A-K steel sheet thickness of .76 mm, with a circular drawbead. Its other parameters are described in Section 4.

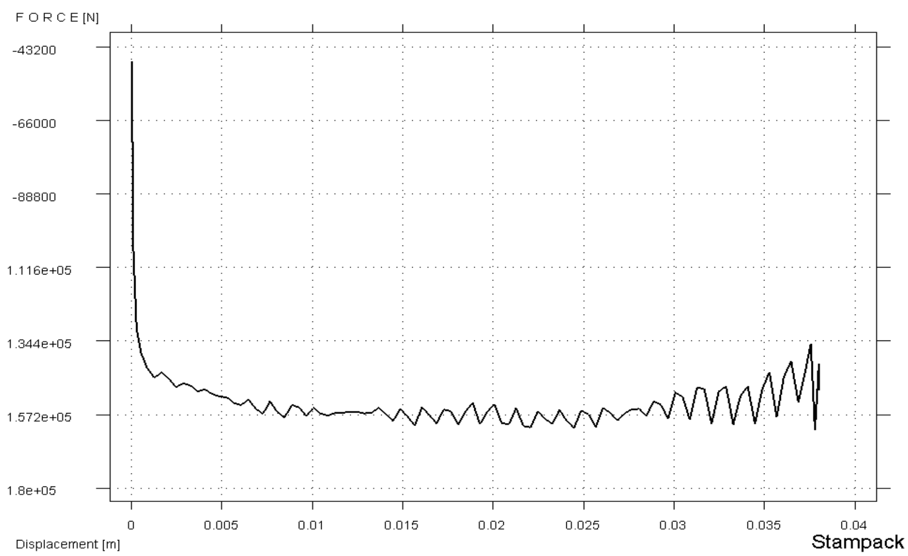

Figure 5. DBRF results simulated in FE: A-K steel sheet thickness equal to .76 mm

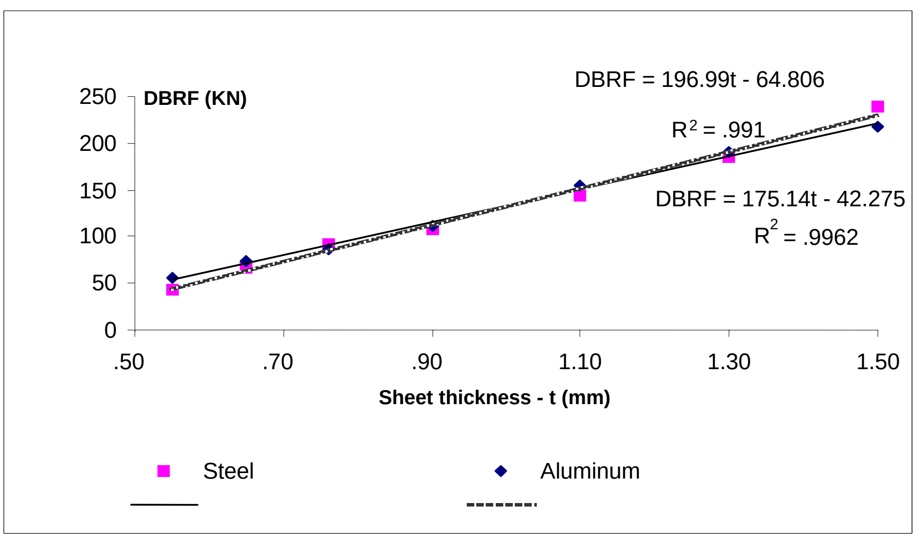

Figure 6. DBRF results for seven different sheet thicknesses simulated for A-K steel and 2036-T4 Aluminum

Figure 6 shows the results obtained from the simulations for each sheet thickness. They were calculated for A-K steel and 2036-T4 Aluminum. These results were obtained after subtracting the Model 2 DBRF from Model 1 DBRF. The figure demonstrates a high correlation between the various thicknesses tested and the calculated DBRF: .991 for steel and .9962 for aluminum. See Section 3. In the same Figure it is possible to verify the linearly increases of the DBRF with respect to sheet thickness. The positive correlation was for both A-K steel and 2036-T4 Aluminum.

The clamping force (BHF) assumed was not sufficient to maintain the blankholder perfectly closed except in the case of the 2036-T4 Aluminum sheet with a thickness of 1.5 mm, as can be seen in Fig. 7. Obviously, in this case, there is a contact area between the sheet and the die of less than the actual area that would be in contact to evaluate the real DBRF. This may explain why the thickest aluminum sheet had a DBRF value of less than the DBRF for the steel sheet of the same thickness.

The research results imply that there were no significant differences in the DBRF values for the two materials used because the conventional elastic limits and isotropic hardening exponent have nearly the same values. This indicates that these parameters predominate over the others listed in Table 1.

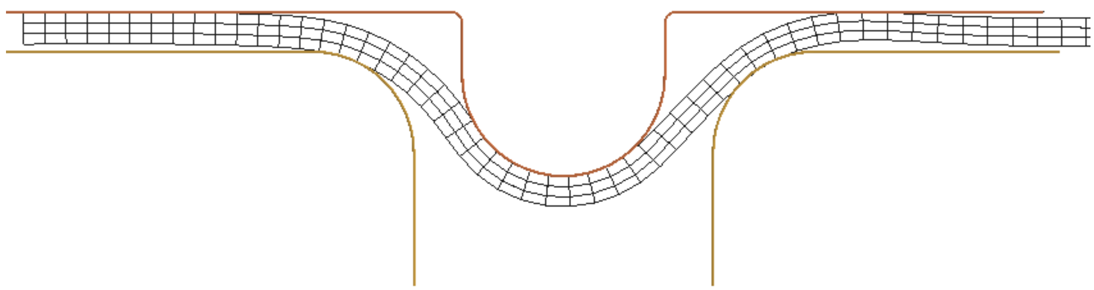

Figure 7. Deformation results for the thickest sheets simulated for 2036-T4 Aluminum

For the maximum and minimum sheet thicknesses there was no excessive deformation, as can be seen in Fig. 8. The maximum deformation of relative thickness in all cases was not superior to 15 per cent. Fig. 8 demonstrates the results simulated for the minimum aluminum sheet thickness: .55 mm.

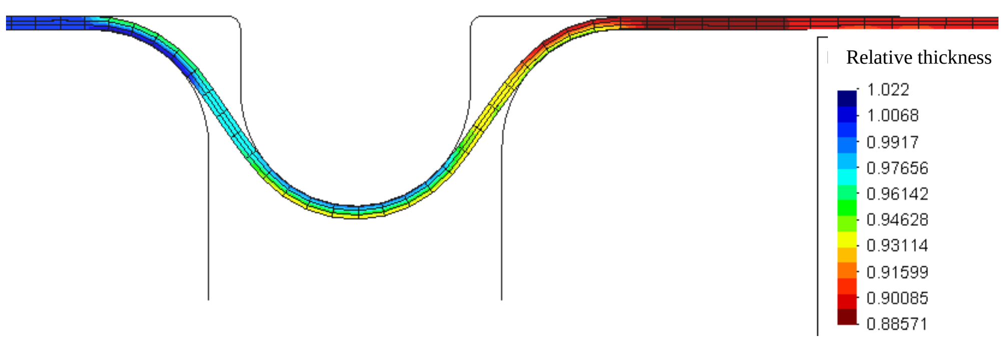

Figure 8. Relative thickness results for the minimal sheet thickness simulated for 2036-T4 Aluminum

5. Conclusions

Two FE models were designed to simulate a sheet metal forming process in order to study the influence of sheet thickness and the friction on the drawbead restraining force – DBRF. Seven different friction coefficient values and seven different sheet thicknesses for two materials: 2036-T4 Aluminum and A-K steel were used.

The validation was conducted for the A-K steel sheet thickness of .76 mm, equal to the values used by the experimental data, (Nine, 1982). The other parameters as well as the material properties were adapted to the values of the experimental data.

For the validation cases the maximum discrepancy was found to be less than 10 per cent.

For the cases studied it is possible to verify that the DBRF increases linearly with respect to sheet thickness. There is a high correlation between the various thicknesses tested and the calculated DBRF: .991 for steel and .9962 for aluminum.

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