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15th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2011, Prague, Czech Republic, 12-18 September 2011

INFLUENCE OF DRAWBEADS POSITION ON RESTRAINING FORCE IN DEEP DRAWING PROCESS

M.Sc. Enes Mujic, dipl.ing.
D.D. "Helios" Banovici
Radnicka 101, 75290 Banovici
Bosnia and Herzegovina

ABSTRACT

In this paper, effect of drawbead location on bead restraining force in the process of deep drawing was investigated. Finite element analysis has been used to understand deformation behavior and stress-strain distribution in a blank material during the forming process. Developed 2D model for computation of drawbead restraining force gives useful information necessary for3D deep drawing simulations and drawing tools design.

Keywords: *deep drawing, drawbeads, finite element model, restraining force.*

1. INTRODUCTION

Drawbeads are commonly used in case of deep drawing of unsymmetrical parts. On classical tool design (without drawbeads) flow of blank material is influenced by blank size and shape, drawing tool geometry and blank-holder friction force. If there are wrinkling problems on some surfaces, it is difficult to correct it because any change in any of those influencing factors has global effects on whole part geometry. Drawbeads are used to restrain material flow locally. It allows increase of tension stresses in blank material after beads that decrease possibility of wrinkling. In Figure 1 drawing tool parts and position of drawbeads are shown. Drawbead consists of round (semi-circular) or rectangular (flat-bottom) bead usually located on blank-holder surface and groove located on opposite (die) surface but opposite arrangement is also possible.

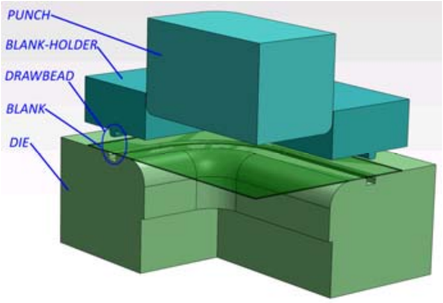


Figure 1. Drawing tool corner parts disposition and location of drawbeads

Direction of restraining force of drawbead is normal to its longitudinal axis and it is generated due to friction and three or four bending-unbending deformations during material flow over bead. The restraining force depends on bead geometry, blank-holder normal force, friction coefficient but also on drawbead position with respect to center of die cavity. Due to complexity, there is no analytical solution for drawbead force calculation in real 3D problems. Also, it is difficult to guess right shape and position of drawbeads. There are some general guidance that drawbead should be 5-10 mm. wide, 1.2-5 mm. high and located at 20-25 mm from the drawing edge. Experimental investigations are expensive and time consuming, therefore numerical simulations are the most prominent way to determine optimal drawbead geometry parameters and locations. It allows formability prediction for deep drawing parts with complex shapes that is sufficient for industrial production.

2. DRAWBEADS MODELING

Classical approach to drawbeads finite element modeling is based on discretization of 3D drawbead model into finite elements, defining contact pairs (master and slave surfaces) and connecting it with rest of tool model as shown in figure 2 (a). Dimensions of drawbeads are much smaller in comparing with other tool parts so the number of elements generated by automatic mesh generator can be very high, hundreds of thousands in many cases. Such nonlinear, inelastic, computationally huge problems are difficult to solve and require lot of time and special hardware. For the practical problems we need efficient methods so the classical FEM model has to be simplified. First, drawing tool parts can be modeled as rigid (non-deformable) bodies with only surface discretized. Drawbeads are modeled by equivalent lines at witch external forces are added, as shown in Figure 2 (b).

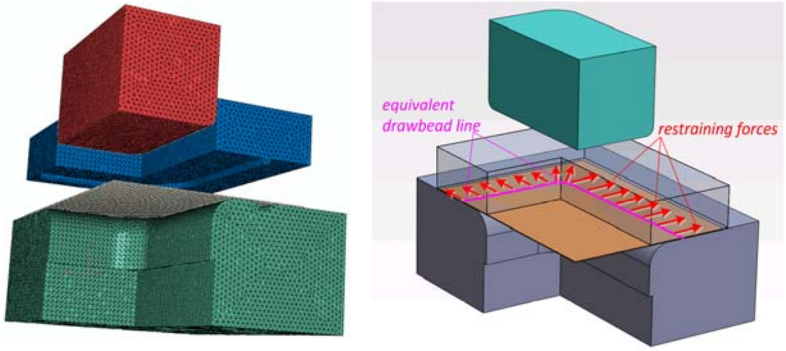
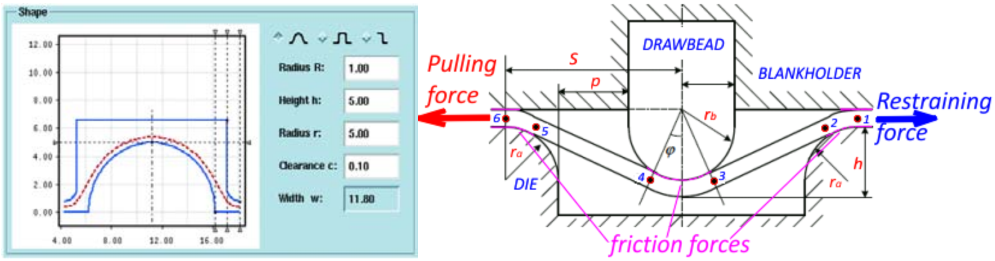


Figure 2. Discretized 3D model with (a) and equivalent 3D drawbead model without drawbead (b)

The drawbead force for equivalent model is computed by 2D finite element simulation for the given drawbead geometry. There are also some analytical solutions for special cases of this problem so term "analytical drawbead model" is frequently used. The majority of deep drawing simulation software uses this approach. Special module "drawbead generator" Figure 3 (a), for the given blank shape and drawbead line calculate necessary drawbead restraining forces. In this paper we use Abaqus/Standard implicit code to do this task. The 2D model for FEM simulation is presented in Figure 3 (b).



Radius R: 1.00

Height h: 5.00

Radius r: 5.00

Clearance c: 0.10

Width w: 11.80

Figure 3. Equivalent 2D drawbead generator (a), model used for restraining force computation (b)

Blank material enters the drawbead at right side and first bending and un-bending deformation take place at right groove shoulder, points 1 and 2. Next, material is deformed under bead semi-circular surface (points 3,4) and finally there is bending un-bending deformation at exit from the drawbead (points 5,6). The restraining force is sum of friction forces depicted in Figure 3 and above mentioned bending-unbending forces. As observed from simulation or experimental measurements, its value (magnitude) is variable, depending on geometry parameters depicted in Figure 3 (h, p, r_a, r_b), normal

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force (blank-holder force), coefficient of friction and blank thickness. For the given geometry of drawbead, besides blank-holder force and sheet thickness, the most influencing parameter on restraining force is drawbead location defined by distance of drawbead center line with respect to center of die radius or to die cavity center. The series of 2D simulation is performed in order to quantify this dependency. The mean or stationary value is calculated from the simulations and used as equivalent drawbead external force normal to equivalent drawbead lines. Those forces can be applied as nonlinear spring elements in 3D model.

3. NUMERICAL SIMULATIONS

The FEM simulation is performed on 2D plane strain and 2D axisymmetric model for the tool corner parts. Tool parts are modeled as rigid analytical surfaces. The blank is slave surface and tool surfaces are contact (master) segments. In order to avoid locking problems, bank is discretized on quadrilateral CPE4R elements with reduced integration and advanced hour-glass control. After completed analysis, some results are presented in figure 4 (a).

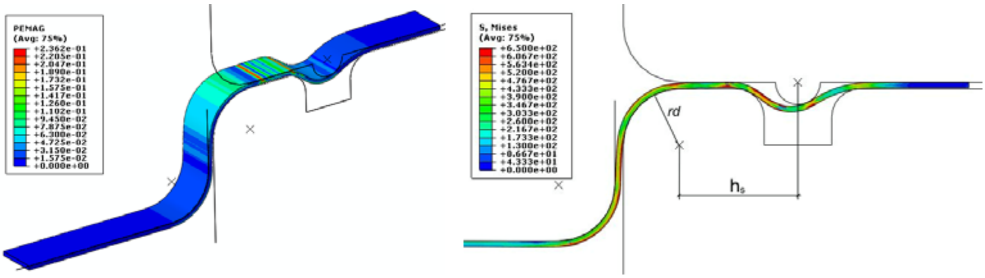

Figure 4 Magnitude of plastic strain distributions, 2D model (a) and vMises stress distribution in material strip after drawbead (b)

First yielding take place at the point directly below drawbead and it is the maximum point in plastic strain magnitude in whole model. Subsequent yielding occurs at shoulders of die channel and die radius. In case of semicircular drawbead profile Figure 5 (a), friction force distribution is asymmetric; the contact takes place at one side only. Therefore, drawbead restraining force for this profile is lesser in magnitude with respect to drawbead profile with flat bottom.

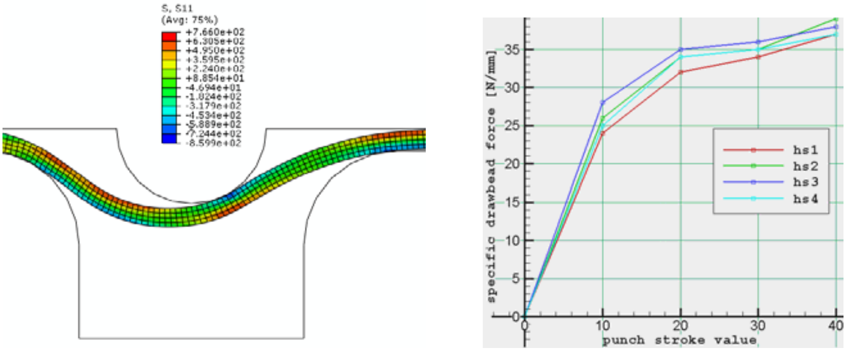

Figure 5 Stress S11 distributions over semicircular drawbead, due to friction (a), dependence of restraining force (F_{res}) on drawbead location (h_s-value) obtained by series of 2D simulations (b)

Influence of drawbead location, dimension h_s in Figure 4 (b) on restraining force is depicted in Figure 5 (b). The force is calculated by integration of S11 stress distribution over blank cross section at left shoulder of drawbead profile. For punch strokes between 10-40 mm, specific restraining force reach approximately stationary value that depends (for given geometry profile) on h_s value. Increasing h_s, this stationary value first slowly increase as shown by red to blue line in Figure 5 (b) but there is some limiting h_s value after which, further increase in h_s actually decrease specific restraining drawbead force. That value can be used as the most appropriate for drawbead design.

4. CONCLUSIONS

The finite element method is the most appropriate technique for numerical analysis of drawbeads effects. In order to get dependence between drawbead design and its restraining force, series of simulations on 2D models with variable geometric parameters have been performed. Average or stationary value of specific restraining force will be used as concentrated external load on 3D models with complicated geometry. In that way we avoided discretization of 3D model in the zone of drawbeads. Preparation of 3D model is simplified, resulting system of equation (NDOF) is much smaller and analysis time is greatly reduced. Analyses can be repeated many times with different drawbead position until satisfactory results are obtained. It is shown that besides geometry and frictional forces the drawbead position (value of h_s) can be used to accomplish necessary level of drawbead force. Certainly, there are some drawbacks in this approach, for example, effects of blank thinning and blank material strain hardening after passing drawbeads are not included in the model. Nevertheless, it is useful approach that allows qualitative insight into problem of drawbead design.

5. REFERENCES

[1] Cao, J. and Boyce, M. C., “Drawbead Penetration as a Control Element of Material Flow” in Sheet-Metal and Stamping Symposium, SAE 930517, Detroit, 1993, pp. 145-153
[2] Carleer B.D., ‘Finite element analysis of deep drawing’, Ph.D. Thesis, University of Twente, Enschede, ISBN 90-90103589, 1997
[3] Carleer B.D., T. Meinders, J. Huétink, “Equivalent drawbead model in finite element simulations”, conference proc. Numisheet, Detroit, 1996, p25-31
[4] Carleer B., J.K. Lee, G.L. Kinzel, R.H. Wagoner (Eds.), Proceedings of the Third International Conference on Numerical Simulation of 3D Sheet Forming, Processes NUMISHEET’96, Dearborn, MI, USA, 1996
[5] Choi, T. H., Huh, H., Chun, B. K. and Lee, J. H., "Drawbead Simulation by an Elasto-Plastic Finite Element Method with Directional Reduced Integration", J. Mater.Process. Technol. **63**, 666-671 (1997).
[6] Dixit, P. M., and Dixit, U. S.: “Modeling of Metal Forming and Machining Processes By Finite Element and Soft Computing Methods,” Springer-Verlag, 2008.
[7] DYNAFORM, “Application Manual”,LSTC, 2008.
[8] Kobayashi, S.: “Metal Forming and the Finite Element Method,” Oxford Univ. Press, New York, 1989.
[9] L.F. Menezes, C. Teodosiu: „Three-dimensional numerical simulation of the deep-drawing process using solid finite elements“, Journal of Materials Processing Technology 97 (2000) 100-106
[10] Mattiasson, K., and Larsson, M., “Numerical Procedure for 2D Drawbead Simulation” Proc. NUMIFORM 2001, pp. 679-685.
[11] Meinders T., Developments in Numerical Simulations of the Real-life Deep Drawing Process, Ph.D. Thesis, University of Twente, Enschede, 2000.
[12] Meinders, T., Geijselasers, H. J. M. and Huetink, J., “Equivalent Drawbead Performance in Deep Drawing Simulations,” Proc. NUMISHEET '99, 1999, pp. 243-248.
[13] Park, J. S., Kim, S. H., and Huh, H.,” Elasto-plastic Finite Element Analysis of Drawbead Forming for Evaluation of Equivalent Boundary Conditions in Sheet Metal Forming”, Transactions of Materials Processing 6, 503-518, (2002)
[14] Schilling A.: „Finite-Elemente-Analyse des Biegeumformens von Blech“, Verlag Stahleisen, Düsseldorf (1992)
[15] T. Hughes, The Finite Element Method, Prentice-Hall, New Jersey, 1987
[16] Wang, M. N., and Shah, V. C., ”Drawabead Design and Performance”, J. Mater. Shaping Technol. **9**, 21-26, (1991).
[17] W. Dahl, R. Kopp, O. Pawelski, „Umformtechnik, Plastomechanik und Werkstoffkunde“, Verlag Stahleisen GmbH, Düsseldorf (1993)
[18] W. F. Hosford, Mechanical Behavior of Materials, Cambridge University Press, 2005.
[19] Ziaeipoor , S. Jamshidifard: „Numerical analysis of wrinkling phenomenon in hydroforming deep drawing with hemispherical punch“, SELECTED TOPICS in SYSTEM SCIENCE and SIMULATION in ENGINEERING, ISBN: 978-960-474-230-1