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EXPERIMENTAL CHARACTERIZATION OF WARM DEEP DRAWING PROCESS FOR EDD STEEL

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Abstract

The experimental characterization has been carried on the warm deep drawing process of extra-deep drawing steel. The results of the experimentation conclude that the extent of thinning at punch corner radius is lower in the warm deep-cup drawing process of EDD steel at 200^0C. it was also found that the peak punch load is low in the warm deep drawing process. The peak load for drawing 73mm diameter blank at 200^0C is lower than drawing 67mm diameter blank at room temperature. The predicted values of thickness using finite element analysis (FEA) are closer to the experimental results.

1. INTRODUCTION

Deep drawing is a metal forming process in which a sheet metal blank is placed over a circular die opening and the same is held in place with a blank holder. A cup is formed when the punch forces the blank into the die cavity while traveling downwards. If the cup height is more than half of its diameter, then it is termed as deep drawing (Figure 1). Ductile materials are easier to be drawn into deeper cups. Both high tensile strength and better ductility in compression are required for the deep drawing material (Jiang et al, 1995).

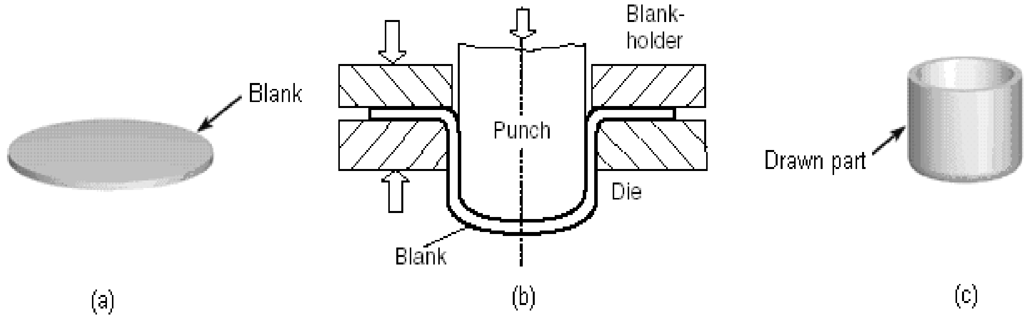


Figure 1: Deep drawing

The important variables involved in the deep drawing process are:

1. properties of sheet metal
2. ratio of blank diameter to punch diameter (draw ratio)
3. clearance between punch and die
4. punch radius
5. die corner radius
6. blank holder force
7. friction and lubrication

Thinning of the cup wall under high longitudinal tensile stresses usually causes failure in deep drawing operation. The cup wall thickness is lowest at the punch radius. The thinnest cup wall thickness determines the maximum stress that can be transferred to the deformation zone. The maximum stress that can be safely transferred from the punch to the blank sets a limit on the maximum blank size. An indicator of material formability or deep drawability is the Limiting Drawing Ratio (LDR), defined as the ratio of the maximum blank diameter to the punch diameter.

The need for the materials having the improved formability has shown the way for the development of Deep Drawing (DD), and Extra-Deep Drawing (EDD) steel sheets and several nonferrous alloy sheets (Ravi Kumar, 2002 and Swaminathan et al, 1991). EDD steels are the most widely used material today for automotive applications involving simple and complex components, which require very high formability. Exterior components, such as starter end covers and petrol tanks, are made up of deep drawing grade steels.

Enhancement of formability leads to maximum possible deformation which reduces the number of production steps and increases productivity. The parts of larger depth or parts of complex geometry can be formed with minimum number of production steps. Therefore, there have been many attempts to improve the formability by improving the properties of sheet metal or by optimization of tool design and process parameters (Sachdeva, 1990; Mohanty, 2000; Kim et al, 2002).

The deep drawing at room temperature has serious difficulties because of the large amount of deformations and high flow stresses of the materials (Bolt, 2001). Thus, deep drawing at elevated temperatures decreases the flow stresses, relieves residual stresses and hence increases the formability of the materials. Lee et al (2007) have investigated the warm formability of a commercial Mg-Al-Zn alloy. The relationship between strain rate and formability was used to predict the failure occurred on square cup deep drawing. Li and Ghosh (2003) have investigated the increase in forming temperature decreases the values of strength coefficient (K) and hardening exponent (n) of aluminum alloys. Greze et al (2010) identified the material parameters of Al-Mg alloy sheets using uniaxial tensile tests at different temperatures and several strain rates in order to take into account both temperature and viscous effects in a coupled thermo mechanical constitutive law. The formability is improved by a uniform temperature increase but the best results were obtained with strong temperature gradients between the tools. For example, in deep drawing experiments with AA5754-O alloy, the limiting drawing ratios can be increased from 2.1 to 2.6 by heating the flange up to 250^0C and cooling the punch to room temperature (Li et al, 2004). Preheating the metal to high temperatures before proceeding to the experiment also increases formability because of stress reliving (Lai et al, 2007). The preheating causes stresses to relieve and increases the formability. The blank during deformation comes in contact with the die and punch and thus experiences frictional force. In deep drawing under warm conditions, as the temperature increases the friction increases, so by providing suitable lubrication the friction can be reduced to certain extent.

Figure 1: Warm deep drawing test rig

In the present investigation, the experiments have been conducted to characterize the warm-deep drawing process of extra-deep drawing steel.

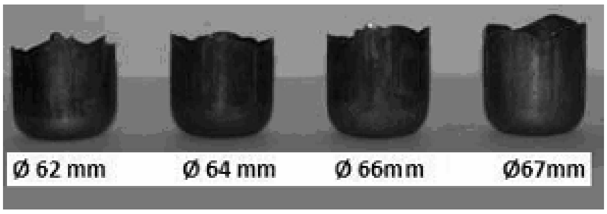
2. EXPERIMENTATION

The experimentations are carried out on a drawing test rig (Figure 1) which is specially designed to carry out the deep drawing operations at elevated temperatures. Since there is tendency in the materials to change dimensions at higher temperatures, the die, blank holder and punch were manufactured using Inconel-600 material. Two sets of furnaces were installed on a 20 tonne hydraulic press. One heater is employed to heat the blank and the other one is attached to the lower die so that blank does not get cold before actual drawing starts. There is a continuous coolant supply provided to the heaters of die and blank. The temperatures are recorded by using pyrometer. The pyrometer is a non-contact temperature detecting instrument. This works on the principle of capturing the wavelength of the radiation emitted by the material. This instrument can be precisely used in measuring the temperatures because by focusing the pyrometer at a particular point. Here the main focus of the temperature is at the centre of the die where the deformation takes place. The data acquisition system which is connected to the press to get the information of punch travel, load applied on the blank, blank holding pressure from the press The data acquisition system produces directly the output in the form of graphs between these variables i.e., graphs of load vs displacement and blank holding pressure vs displacement. The chemical composition of the EDD steel sheets is given in Table 1.

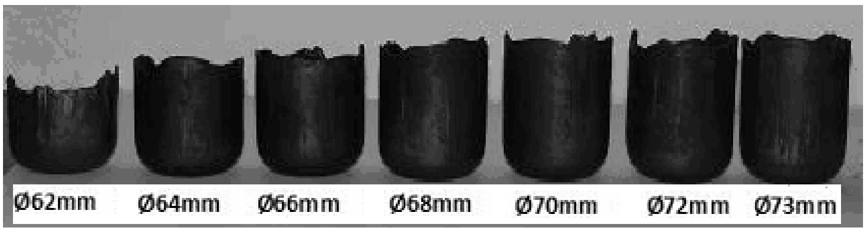
Table 1 : Chemical composition of EDD steel sheets (in weight percent)

Element	C	Sn	Si	Cu	Mn	Ni	S	Mo	P	Cr	Fe
% weight	0.048	0.004	0.83	0.019	0.39	0.054	0.024	0.028	0.019	0.027	Rest

The blanks are made into circular shape by using shearing and grinding machine. The die is heated and when the die reaches the required preheat temperature, lubricant is applied so that the friction at the elevated temperature can be reduced. The lubrication used for the reduction of friction between die and punch assembly is Molycote. It contains Molybdenum base material which is highly effective at elevated temperature. The blank is also heated (since the blank will get heated up very fast, so heating of blank is done after the die is heated). The blank temperature is controlled to prevent from overheating by means of water circulation from cooling tower. The preheated blank is placed on the die and the drawing operation is performed. The LDR value of the EDD steels is determined by performing a series of deep drawing tests on the circular blanks of 1mm thickness by varying the diameter. The cups drawn by the warm deep drawing process are shown in Figure 2.



Room temperature of 25^0C



Temperature of 200^0C

Figure 2 : Cups of different diameters drawn at different temperatures

3. RESULTS AND DISCUSSION

Comparisons of thickness distribution in the drawn cups of 62 and 64mm diameter at room temperature and at 200^{0}C are shown Figure 3. As the diameter increases, the tendency of thinning at the cup corner increases due to increase in the load, more residual stresses and stress concentration at punch corner. When the same diameter blank is drawn at 200^{0}C, it can be observed that extent of thinning at punch corner radius is lower primarily due to decrease in punch load as observed in Figure 4. While drawing 64mm diameter blank, the peak punch load decreases from 21.5KN to 17.5KN. For 66mm diameter blank the punch load decreases from 24KN to 19KN. This is primarily due to partial revealing of residual stresses and decrease in flow stresses of material at elevated temperature. From figure 5, it can be understood that even at LDR, the peak load for drawing 73mm diameter blank at 200^{0}C is lower than drawing 67mm diameter blank at room temperature. Fig 6 indicates the thickness distribution in the drawn cup at LDR for both at room temperature and 200^{0}C. It is observed in this Fig 6 that the extent of thinning is more at room temperature and thickness are more uniformly distributed while drawing at 200^{0}C.

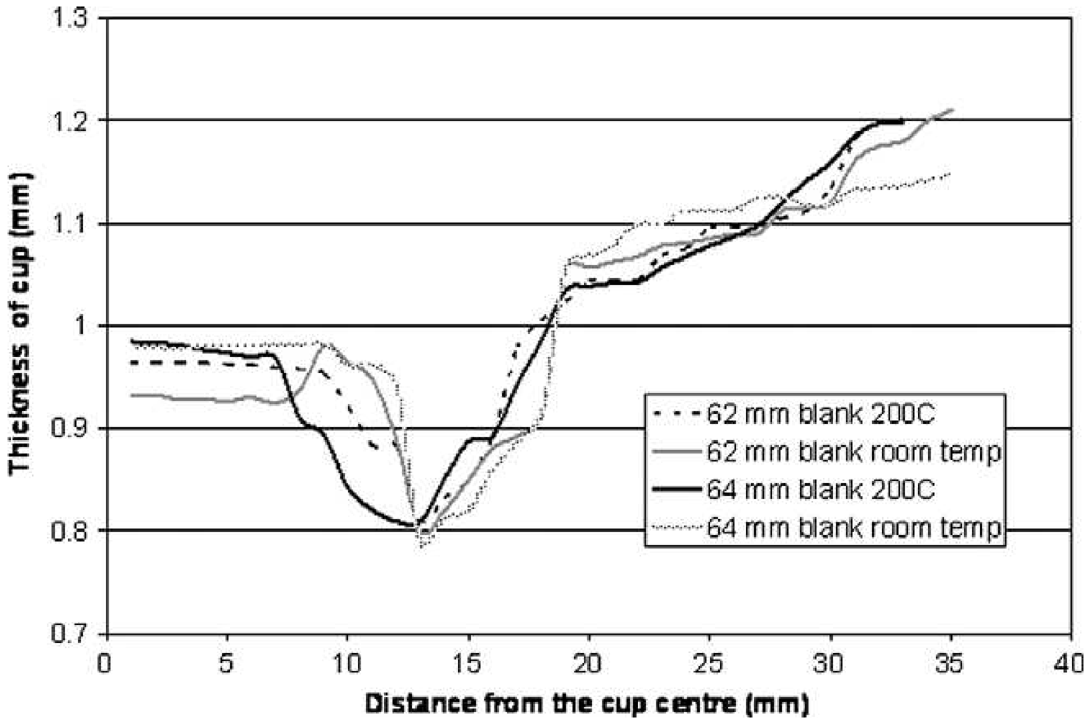


Figure 3 : Comparison of thickness distribution of experimentally drawn cups of 62 and 64 mm diameter blank for room temperature and at 200^{0}C.

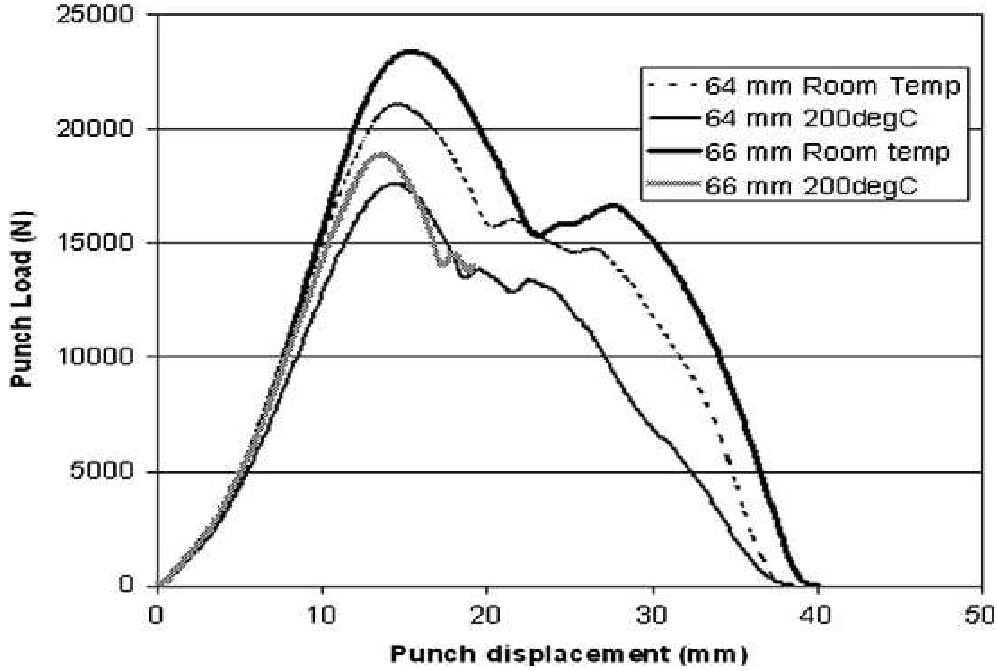


Figure 4 : A comparison of experimental punch load vs. displacement diagram for deep drawing at room temperature and at 200^{0}C for constant blank diameter.

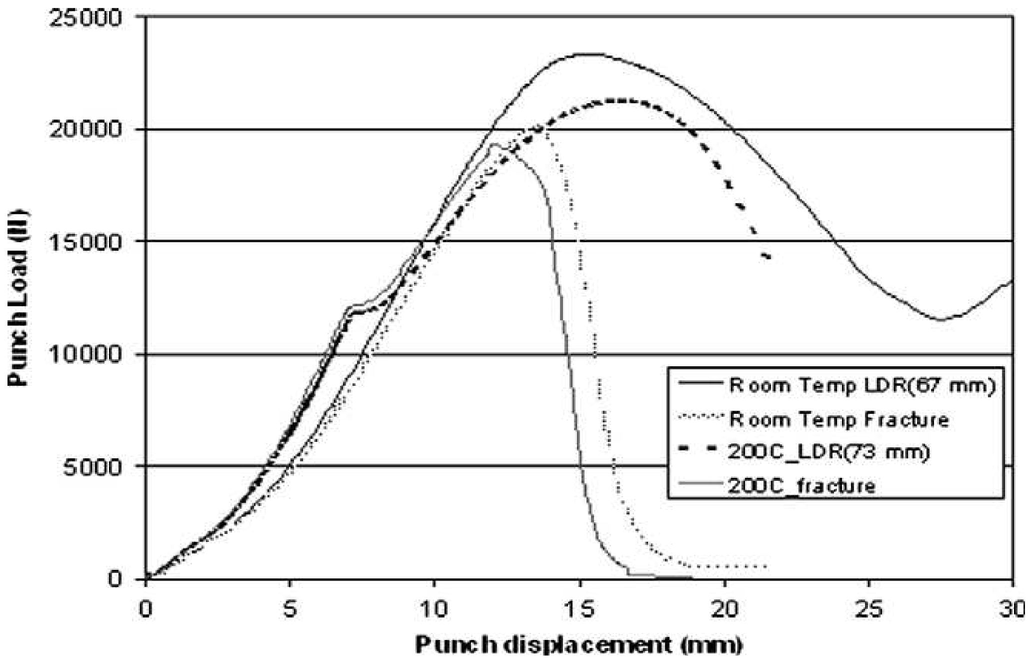


Figure 5 : Comparison of experimental punch load vs displacement for deep drawing at room temperature and at 200^{0}C at limiting draw ratio (LDR).

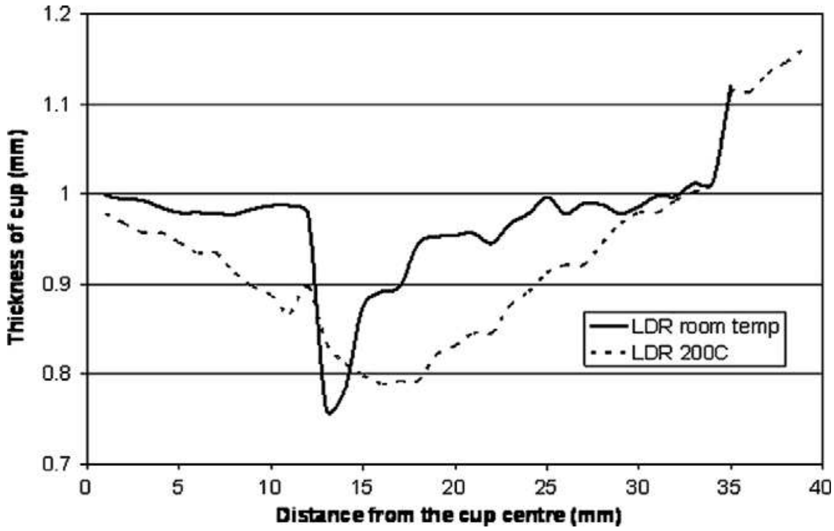


Figure 6 : Comparison of thickness distribution of experimentally drawn cups at limiting draw ratio (LDR) for room temperature and at 200^{0}C.

In the present investigation it can be seen from Fig 3 and 6 that at the same diameter by increasing the temperature, the tendency of thinning decreases primarily because of low mean flow stresses as it is reflected by load curves (Fig 4 and 5).

It can also be observed from the figure 7 that the predicted values of thickness using finite element analysis (FEA) are closer to the experimental results. The variation between the experimental and FEA results is due the effect of both normal and planar anisotropy in the yielding behavior of the material.

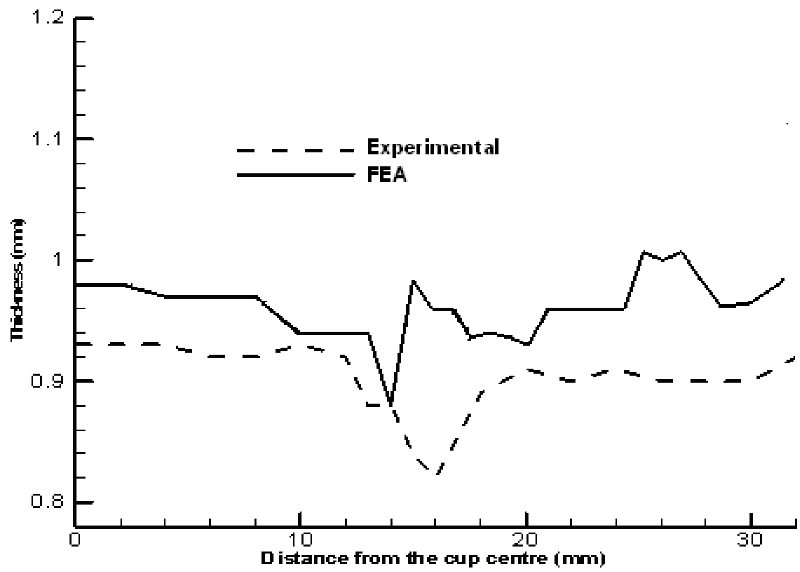


Figure 7 : A comparison of thickness variation from experiments with FEM results

CONCLUSION

The extent of thinning at punch corner radius is lower in the warm deep-cup drawing process of EDD steel at 200^0C. in the warm deep drawing process, the peak punch load decreases on account of partial revealing of residual stresses and decrease in flow stresses of material. The peak load for drawing 73mm diameter blank at 200^0C is lower than drawing 67mm diameter blank at room temperature. The predicted values of thickness using finite element analysis (FEA) are closer to the experimental results.

REFERENCES

[1] Jiang, J, Collado, C, Keeley, D, Dodd, B (1995) "Room temperature formability of particle reinforced metal matrix composites: forging, extrusion and deep drawing", Composites, 26(11), 785-9.

[2] Ravi Kumar, D (2002), "Formability analysis of extra-deep drawing steel", Journal of Material Process and Technology, 130, 31-41.

[3] Swaminathan, K, Pandmanabhan, K.A (1991) "Some investigation on the forming behavior of indigenous extra deep drawing low carbon steel", Transactions of Indian Institute of Metals, 44, 231-47.

[4] Sachdeva, A. K (1990), "Development of an Aluminum sheet alloy with improved formability", Metallurgical Transactions, 21A, 165-175.

[5] Mohanty, O. N,(2000), "Developments in automobile steel grades-experience at Tata steel", Iron and Steel review, 19-27.

[6] Kim, Y. H. and Park, J. J, (2002), "Effect of process parameters on formability in incremental forming of sheet metal", Journal of Material Processing Technology, Vol. 131, 42-46.

[7] Bolt, P.J, Lamboo, N.A.P.M, Rozier, P.J.C.M, (2001), "Feasibility of warm drawing of Al products", Journal of Material Process and Technology, 115, 118-121.

[8] Lee, Y.S, Kim, M.., Kim, S.W, Kwon, Y.N, Choi, S.W, Lee, J.H, (2007), "Experimental and analysis for forming limit of AZ31 alloy on warm sheet metal forming", Journal of Material Process and Technology, 187-188, 103-107.

[9] Li Daoming, Amit Ghosh, (2003), "Tensile deformation behavior of aluminum alloys at warm forming temperatures", Material Science of Engineering A, 352(1-2), 279-86.

[10] Greze, R, Manach, P.Y, Laurent, H, Thuillier, S, Menezes, L.F, (2010), "Influence of the temperature on residual stresses and spring back effect in an aluminum alloy", International journal of mechanical sciences, 26.

[11] Li, D, Ghosh, A, (2004), "Biaxial warm forming of aluminum alloy sheet alloys", Journal of Material Process and Technology. 145, 281-293.

[12] Lai, C.P., Chan, L.C, Chow, C.L, (2007), "Effects of tooling temperatures on formability of Titanium TWB's at elevated temperatures", Journal of Materials Processing Technology, 191, 157-160.

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