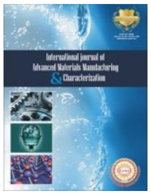

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Redrawing of EDD steel at elevated temperature

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In the present paper the drawability of extra deep drawing steel was estimated in two stage forward redrawing process. The EDD steel sheets of one millimeter thickness were cut into circular blanks of diameter 80mm, 82mm and 84mm.Deep drawing and redrawing experiments were carried out successfully on hydraulic press by using specially designed super alloy dies at room temperature and at elevated temperatures. The effects of process parameters on the final product quality were discussed. The experimental results were analyzed and the process defects of local thinning were predicted and thickness variations were discussed.

1.Introduction

There has been a continuing trend towards development of materials with improved formability, which led to development of deep drawing quality and extra-deep drawing quality steel sheets and several nonferrous alloys. Extra deep drawing (EDD) steels are the most widely used steel material today for automotive applications involving simple and complex components , which require very high formability. Exterior components such as starter end covers, petrol tanks, are made up of deep drawing grade steels. The low carbon steel sheets are also used extensively in enamelling applications such as baths, sink units, kitchenware, and cooker and refrigerator panels.

In today's practical and cost-conscious world, sheet metal parts are fast replacing many expensive cast, forged and machined products. The reason is obviously relative low cost, high productivity and greater control over technical and aesthetic parameters.Many engineering applications employ cups of various shapes and sizes drawn from sheet metal. Drawing is the most widely used sheet metal operation for manufacture of cups. Very deep cups are required in substantial number of these applications. Various means are resorted to obtain deeper cups. They include assistance of hydraulic pressure, which helped in increasing the draw ratio up to 3.5, in a recently introduced process [1-3]. Maslennikov's technique is another method which produces very deep cups at a draw ratio of 6 or more from flat blanks [4-8]. Ironing is another technique used to lengthen the wall of the cup with reduced thickness while keeping the bottom of the cup with the same thickness as the original cup [9-10].

Redrawing is one of the processes used for manufacture of deep cups. Drawing is a sheet metal process during which a flat piece of sheet metal material (called as blank) is transformed into a hollow, three-dimensional object. Such transformation can be produced in a single step or in a sequence of operations, each of them changing the shape partially. This is a complex forming process which involves tension (cup wall), bending (punch and die corners) and compression (cup flange). The draw ratio in the first stage of deep drawing is usually limited to 2.2. If the first stage cup is drawn at a comfortable draw ratio 2 and the resulting cup is redrawn at a higher ratio of 3, then an overall draw ratio of 6 can be achieved in just two steps. Thus, it becomes very attractive to manufacture very deep cups in just two steps, especially in small volume production. During deep drawing process of sheet metals, the blanks deform from their initial flat shape to the final product shape which is a cup. In redrawing process cups drawn by conventional deep drawing are utilised. In direct redrawing, punch is always in contact with the same side of the cup. In reverse redrawing, the inner side of the original cup becomes the outer side of the redrawn cup and vice versa. The punch will come in contact with the surface other than that in the deep drawing process.

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2.Experimental methodology:
2.1Material(EDD STEEL) & Properties:

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

EDD is a steel that typically contains less than 0.005% carbon content. It has excellent formability and exihibits a high resistance to thinning during drawing. However, conventional high strength sheet steels have insufficient formability to meet the drawing requirements of today's applications like complex outerbody car panels. The chemical composition of EDD steel is given below. EDD is produced from vacuum degassed steel to achieve a very low carbon content it is chemically stabilised with elements such as titanium and niobium(coloumbium) during production to combine remaining residual amounts of carbon and nitrogen to make it "interstitial free. Excellent uniformity and exceptional formability characterise coated and uncoated sheet of this quality the final product is excellent for deep drawn parts in that the steel exihibits a high resistance to thinning during drawing. EDD steel is non ageing, thus coil brakes, strain lines and fluting during fabrication are not encounterd. The mechanical properties is shown in the table below.

Figure 1 Direct redrawing die assemblies

TEMPERATURE (0C)	UTS (M Pa)	YS (MPa)	STRAIN AT YS	ELONGATION (%)	STRENGTH COEFFICIENT (K) (MPa)	WORK HARDENING EXPONENT (n)
25(RT)	337	202	0.0222	44	677	0.304
150	304	188	0.0291	35	577	0.274
300	294	184	0.0314	29	548	0.289
450	329	216	0.0582	39	684	0.261

2.2 DESIGN OF TOOLING:

The drawing operations of extra deep drawing material is performed on a experimental test rig. Initially required circular blanks of diameters 80, 82 and 84 millimeters are cut with the help of a lathe machine. The experimental test rig having 20 tonne capacity on which the operations are being performed is shown in the Figure 1. Blank is placed on the lower die and it is centred perfectly. The deep drawing and redrawing operations at elevated temperatures can be performed on this experimental set up. The dies used in this operations are made of nickel based super alloy, while H13 material was used for manufacturing the punch and the blank holder.Induction heating system is provided around the lower die to heat up to 600^{0}C.

Exterior components such as starter end covers, petrol tanks, are made up of deep drawing grade steels. The low carbon steel sheets are also used extensively in enamelling applications such as baths, sink units, kitchenware, and cooker and refrigerator panels. The fig shows representation of deep drawing.

2.3 DEEP DRAWING

Deep drawing is a complex forming process which involves tension (cup wall), bending (punch and die corners) and compression (cup flange). Both high tensile strength and better ductility in compression are required for the deep drawing material. Although the deep drawing process of high strength/low formability metals has an extensive industrial application area, deep drawing at room temperature has serious difficulties because of the large amount of deformations and high flow stresses of the materials . Thus drawing at elevated temperatures decreases the flow stresses, relieve residual stresses and hence increases the formability of the materials as deformations become easier [11].

Due to the manufacture requirement of wide variety of product we need the product to be manufactured at a low production cost with high process flexibility for the various requirements related to the quality of products, or material properties. In particular, with the progress of the miniaturization of mechanical elements, the need for high accuracy products has intensified. So we need to build an optimal design derived from understanding the actual phenomenon of material deformation, the variation of material deformation, the variation of material properties and interfacial phenomena in the process. In particular, the accuracy of products and the occurrence of forming failure such as fracture or wrinkling, during sheet metal forming are strongly influenced by the frictional behaviour between the sheet and tools which helps in the analysis of the deep drawing [12] and also the finite element analysis..

2.4 REDRAWING

Redrawing is of two types; they are forward redrawing and reverse redrawing. The reverse redrawing process was found to be advantageous compared with the forward redrawing process since it allows higher reduction ratios and exhibits several technological advantages. Based on the equilibrium equations and considering strain hardening and sheet thickness changes, some simplified analytical approach for the multi-stage drawing of round cups. It was concluded from experiments that direct redrawing allows for higher total drawing ratios than reverse redrawing. Furthermore, it showed that the limiting drawing ratio for the second drawing stage decreases and the total achievable drawing ratio increases with increasing first stage drawing ratio.

There is an impact of process parameters of mould profile radius, punch and die clearance and lubricants on the circular cup drawing ratio. It is found that the contact stress distributions on the blank thickness and binder force on the mould surface were irregular and the blank thickness and mould radius of rounded corner had great influence on the maximum value of contact stress. The thicker the blank or smaller the radius is, the greater contact stress.

3. RESULTS AND DISCUSSIONS:

In the present work, cups of 80, 82, 84 mm are drawn from room temperature to 350°C. These cups are shown in figures 2 to 5.

3.1 DRAWING AT VARIOUS TEMPERATURES

Figure 2 shows the cups of diameter 80 82 and 84 mm drawn at room temperature. While drawing 82mm diameter blank, there was a fracture in the drawn because the material had reached its limiting drawing ratio (LDR). Naturally it is known that by increasing the temperature of the sample, draw ability increases due to decrease in the mean flow stresses.

Figure 2 : Various diameter cups drawn at room temperature

Figure 3 cups of various diameters drawn at 150^{o}C

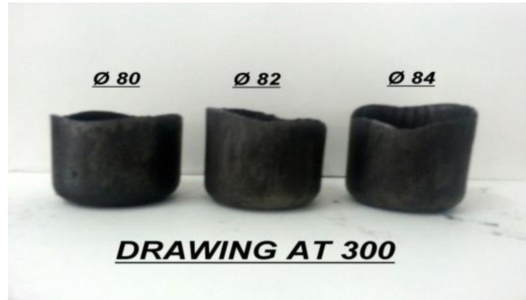

Figure 4 cups of various diameters drawn at 300^{o}C

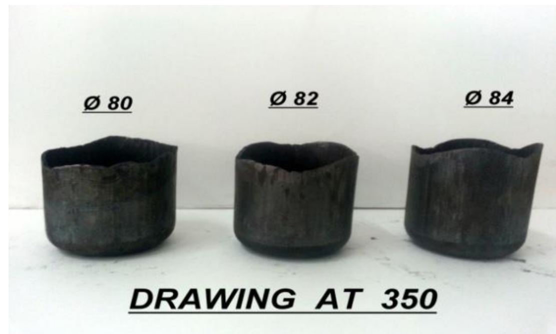

Figure 5 cups of various diameters drawn at 350^{o}C

Figures 2 to Figure 5 shows blanks of diameters 80, 82 and 84 mm at room temperature and elevated temperatures of 150 ^{c}o, 300 ^{c}o and 350^{o}C.Where as the Figure 6 shows failure at room temperature

3.2 FAILURE AT ROOM TEMPERATURE

The EDD blanks of diameter 84mm cannot be drawn into cups. Figure 5 Shows the cups which are failed at room temperature, the reason for failure of these cups is due to exceeding draw ratio.

Figure 6 cups failed at room temperature

3.3 REDRAWING AT VARIOUS TEMPERATURES

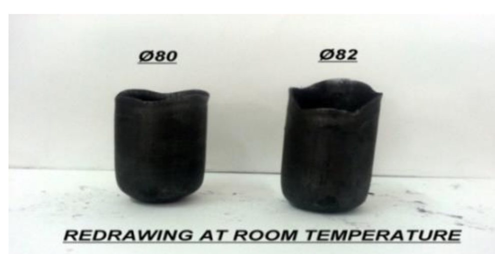

Figure 7 cups redrawn at room temperature

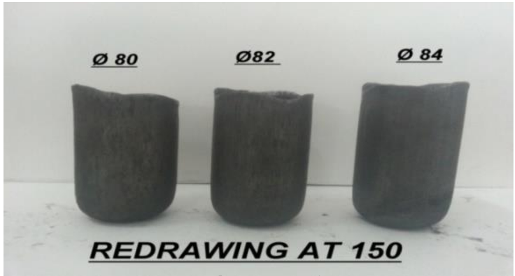

Figure 8 cups redrawn at 150^{0}C

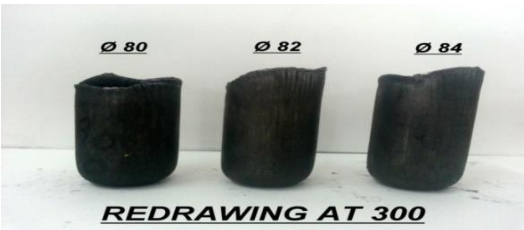

Figure 9 cups redrawn at 300^{0}C

Figure 10 cups redrawn at 350^{0}C

Figure 11 cup failed in redrawing

Figure 12 Drawn cups with wrinkling defects

As it can be observed that by increasing the temperature formability of material increases due to decrease in mean flow stresses [13-15]. This phenomenon can be seen in Figure 13 that load required at high temperature is slightly lower than the load required at elevated temperature. Comparison of thickness distribution in the drawn cup of 80 and 84 mm diameter room temperature and at 150^{o}C was shown in Fig 15. As expected it can be observed that as the diameter increases, tendency of thinning at the cup corner increases due to increases in the load, more residual stresses and stress concentration at punch corner. When the same diameter blank is drawn at 150, it can be observed that extent of thinning at punch corner radius is lower primarily due to decrease in punch load as observed in Fig.13 that while drawing 84 mm diameter blank the peak punch load decreases from 21.5 KN to 17.5 KN. For 66 mm diameter blank the punch load decreases from 24 KN to 19 KN. This is primarily due to partial revealing of residual stresses and decrease in flow stresses of material at elevated temperature. Similar trend was observed for EDD steel in normal drawing process [14].

3.4 LOAD VS DISPLACEMENT GRAPHS

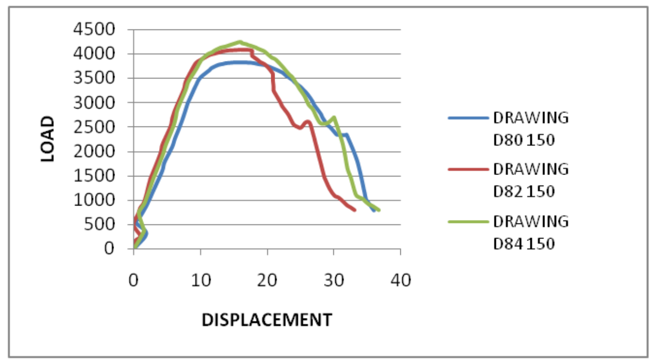

Figure 13 Load Vs displacement graph for drawing at 150^{0}C

After drawing these cups in first stage again redrawn by using direct redrawing dies. Fig.13 and Fig.14 shows the load Vs displacement graph for direct as well as redrawing operation at 150^{o}C and 350^{o}C. It can be seen from this diagram that for same diameter, load required to deform the material is less in case of redrawing as compared to direct drawing process. It is because of decrease in contact area between blank holder and blank material.

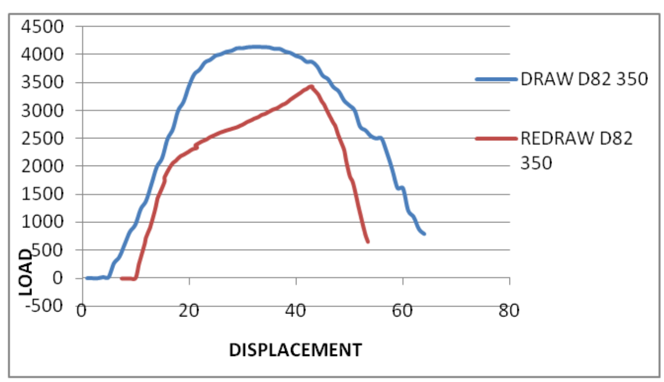

Figure 14 Load Vs displacement for drawing and redrawing at 350^{0}C

3.5 DISTANCES FROM CENTER VS THICKNESS GRAPHS

Fig.15 and Fig.16 describes the thickness plots in drawn as well as redrawn cups. As expected it can be seen in Fig 15 that by increasing the diameter, thinning near punch corner increases this is primarily due to increase in the load. Larger is the diameter of the blank. Larger force is required to deform the material. In the present investigation it can be seen that at the same diameter by increasing the temperature the tendency of thinning decreases primarily because of lower mean flow stresses as it is reflected by load curves but in case of fluid assisted deep drawing large amount of drawing loads are required due to the presence of counter pressure.

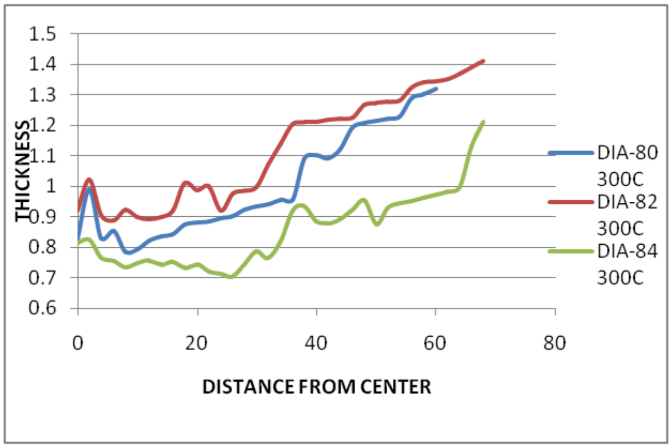

Figure 15 Distance from the centre Vs thickness for various diameters

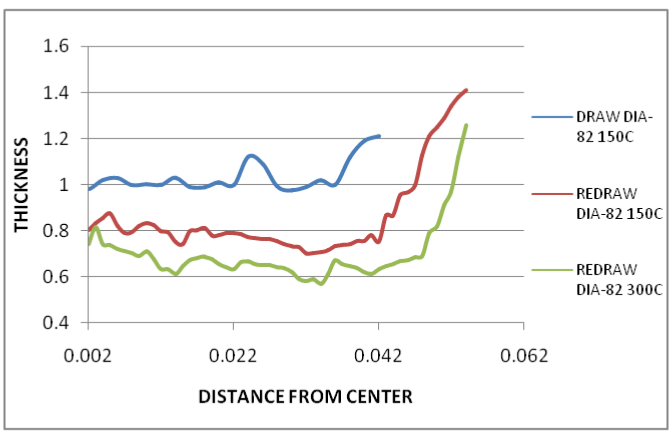

Figure 16 Distance from the centre Vs thickness for 82mm blank at draw and redraw

From Fig.16 it can be seen that at 300ºC thicknesses in drawn cup are more uniform and these thickness fluctuates in very narrow range. This is again due to decrease in mean flow stress by raising the temperature. Figure 16 shows that comparison of thickness patterns in drawing and redrawing operations. Since in redrawing operation we are again stressing up the material and this will further increase the thinning process in drawn cup. And this phenomenon can be seen from Figure16 that minimum thickness in drawn up by redrawing operation is significantly less than the cup drawn in direct drawing process. By increasing the temperature further tendency of thinning go down because of reduction of further mean flow stresses. It was found that while deep drawing at higher temperatures there is an increase in LDR value due to residual stress relieving and decrease in flow stress of material and while drawing at elevated temperatures there is uniformly distribution of thickness throughout the cup wall and this was justified by using experimentation.

Conclusions:

It is observed that EDD material blanks with various diameters at room temperature, 150°C, 300° C and 350°C were drawn successfully. Direct redrawing has been a successful attempted. The graphs drawn between load Vs displacement and distance from centre Vs thickness. It clearly depicts that the fractures which have occurred are either due to increase in blank holding pressure, exceeding the Limiting Draw Ratio. Hence by redrawing process high draw ratios can be achieved in less number of steps and deeper cups can be obtained.

References:

1. S.Thiruvarudchelvan, A novel hydraulic pressure augmented deep drawing process for high draw ratios, J. Mater.Proc.Technol. 54 (1995) 355–361
2. S. Thiruvarudchelvan, H.B. Wang, G. Seet, Hydraulic pressure enhances the deep drawing process yielding deeper cups, J. Mater.Proc. Technol. 82 (1-3)(1998) 156-164 .
3. S.thiruvarudhchavan,H.B.Wang.Invesigations into the hydraulic pressure augmented deep drawing process 105 (2000) 161-175.
4. M. Fakuda, K Yamaguchi, K. Takayama, Deep drawing of circular sheet metals with rubber rings, Bull. JSME 15 (1972) 401–408.
5. M. Fakuda, K Yamaguchi, K. Takayama, Deep drawing of circular sheet metals with rubber rings, Bull. JSME 17 (1977) 554–561.
6. M. Fakuda, K Yamaguchi, T. Nishikoji, Deep drawing of circular sheet metals with rubber rings, Bull. JSME 17 (1977) 1513–1521
7. K. Yamaguchi, N. Takakura, M. Fakuda, Attempts to facilitate low volume production of soft aluminium cups with large drawing ratios by deep drawing ratios by deep drawing based on Maslennikov's technique, J. Mech. Work. Technol. 2 (1979) 357–366.
8. K. Nakamura, T. Nakagawa, Reverse deep drawing with hydraulic counter pressure using the peripheral pushing effect, Ann.CIRP 35 (1986) 173–176.
9. Swadesh Kumar Singh, PV Sasidhar, P Prudvi Reddy, Vinay Kumar,MS Hallika and AK Gupta, " Study of Formability and Friction in Warm Forming of Aluminum IS 737 Alloy" International Journal of Advanced Materials Manufacturing and Characterization for Vol 1, Issue 2, 2012, pp209-216.
10. S.Thiruvarudchelvan,Directbredrawing of cups using an annular urethane pad.journal of material processing Technology 123(2002) 71-74
11. Lade Jayahari, PV Sasidhar, P Prudvi Reddy, B. Balu Naik, AK Gupta and **Swadesh Kumar Singh**, " Formability

studies of ASS 304 and Aluminum and evaluation of friction in deep drawing setup at elevated temperatures using LS-DYNA" Journal of King Saud University - Engineering Sciences, Elsevier Vol. 26, Issue 1, 2014, pp 21-31

12. K. Rakesh Varma, PAPN Varma, KGK Murti, AVS Raju and **Swadesh Kumar Singh**, "Mathematical modelling and experimental validation of excessive ironing of EDD steel in deep drawing setup in Warm conditions" International Journal of Advanced Material Manufacturing and Characterization, Vol. 1, No 1, 2012, pp 165-172.
13. Swadesh Kumar Singh, M. Swathi, Apurv Kumar and K. Mahesh (2010), "Understanding formability of EDD steel at elevated temperatures using finite element simulation" Materials and Design Vol. 31, pp 4478–4484.
14. Swadesh Kumar Singh, Amit Kumar Gupta and K. Mahesh(2010), "Prediction of mechanical properties of extra deep drawn steel in blue brittle region using Artificial Neural Network" Materials and Design, Vol. 31, pp 2288-2295. (Elsevier, Impact factor 1.107).
15. Swadesh Kumar Singh (2010), "Development of ANN Model And Study The Effect of Temperature on Strain Ratio and Sensitivity Index of EDD Steel" International Journal of Material Forming, Vol 3, pp 256 - 266.