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SOME ASPECTS OF FORMABILITY OF ASS 304 UNDER WARM CONDITIONS

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ABSTRACT

In this study Austenitic stainless steel 304 (ASS-304) are deep drawn under warm conditions and by using 20Ton hydraulic press, there is an increase in formability as the temperature increases. Experiments are conducted to study the thickness distribution at various temperatures and also analyzed the safe blank diameter that can be drawn without fracture. Vickers microhardness test is performed on cut section of deep drawn molded cup samples at neck, base and wall region for different blank diameters and variable temperature. It is observed that microhardness depends considerably in the drawn cup depending upon the region and the temperature at which the material is drawn.

Keywords: *Warm forming, Deep drawing, ASS-304 and Microhardness*

1. Introduction

Austenitic stainless steels (ASS) are one of most frequently used high strength and high temperature resistance structural materials [1]. Austenitic stainless steel has great resistance to environmental attack, with more life time and mechanical properties like yield strength, UTS, ductility, formability toughness and corrosion resistance in marine, organic and environmental conditions are suitable for forming. Austenitic stainless steels are an extraordinary family of alloys that have exceptional welding characteristics by all standard fusion methods, both with and without filler metals. They have unsurpassed strength and toughness among the commercially viable alloys from cryogenic to elevated temperatures. [2]. Because of low yield strength the engineering applications of Austenitic stainless steel are limited [3]. In ASS-304 Chromium increases toughness, corrosive resistance and deep hardening ability. Alloying Manganese will increases strength, hardness and deoxidizes, element like silicon also increases deoxidization which will increases susceptibility of steel to decarburization and graphitization. Limiting drawing ratio LDR defines the ratio of maximum diameter of blank that can be drawn into cup safely without fracture to the diameter of punch. LDR measures the formability of deep drawn materials. Warm mechanical deep drawing raises limiting draw ratio [4]. Gupta et. al.[5] investigated the constitutive modeling of ASS-304 at elevated temperature to understand the formability of this material at elevated temperature. Thickness in the drawn cup at the punch corner will be lower because maximum load is appearing on the material in this region. Since compressive hoop stress appears in the flange region so thickness of the drawn cup on wall region increases. As the diameter of the blank increases, thickness of the drawn cup in the punch corner region will decrease. Once the thickness reaches a particular value fracture will appear in the drawn cup. Austenitic Stainless sheets are extensively used in nuclear, automobile, aviation, etc., because of high strength and corrosive resistance. Austenitic stainless steel-type 304 sheets are mostly used for forming since they are very superior in forming different structured products. Researchers [6, 7, 8] have reported that the micro indentation test is the effective method of studying the deformation of the material. Pyramid indenters are less affected by elastic release and its contact pressure is independent of indentation size. Hence Pyramid indenters such as Vickers microhardness indenter is said to be best suited for hardness tests.

2. Material and Experimentation

ASS 304 is the standard "18/8" stainless steel. It is the most versatile and standard alloy widely used stainless steel, available in a wider range of products since it has lower carbon levels, easily attainable and economical. The balanced austenitic structure of Grade 304 enables it to be severely deep drawn without intermediate annealing, which has made this grade dominant in the manufacture of drawn stainless parts such as sinks, hollow-ware and sauce- -pans. Type 304 is readily brake or roll formed into a variety of

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components for applications in the industrial, architectural, and transportation fields.

Type 304L, the low carbon type of 304, does not require post-weld annealing and so is extensively used in heavy gauge components. Type 304H with its higher carbon finds application at elevated temperatures. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures.

2.1 Experimental setup

The experimental investigations were carried out on the test rig as shown in (Fig.1). The set up is designed to perform sheet metal forming operation like deep drawing at elevated temperature. While designing the test rig care has been taken that during experimentation at higher temperature the testing materials dimensions should not change, for that the die, punch and blank holder are made of Ni based super alloy material. It is because ASS-304 material is very strong even at higher temperatures and to deform it dies should be even stronger and simultaneously dies should not change any dimensions while heating. The blanks are made into circular shape by lathe machine or by shearing and grinding machine.

Fig. 1 Experimental Test Rig with Induction Furnace Developed to Draw the High Sttrength Materials at Elevated Temperature

Die is heated to the required temperature using the induction furnace attached to the die (Fig. 1). Friction plays a very important role in the sheet metal forming and by increase in the temperature there will be increase in friction which will reduce the formability of material. So in the present investigation a Mo based lubricant Molycote is used to reduce the friction between die material and the blank. While deep drawing at elevated temperature care has to be taken for Austenitic stainless materials that immediately after heating, there is a chance of formation of Martensite Structure. So heating of the dies and blanks were done gradually. Drawn cups at various temperatures and these cups are cut into two halves with the help of hack saw tool and the best piece is selected for thickness measurement and same cut piece is moulded for hardness measurement. Pointed digital micrometer is used to measure thickness from centre of the cup to end along the wall. The graphs drawn at different blank diameters and at various temperatures are superimposed accordingly for analysis and comparisons

3. Results and Discussions

3.1 ASS-304 formability analyses

The maximum stress that can be safely transferred from the punch to the blank sets a limit on the maximum blank size (initial blank diameter in the case of rotationally symmetrical blanks). LDR is obtained at room temperature on 65mm blank, 150^0C on 75mmblank and at 300^0C on 70mm blank. Determination of the LDR for complex components is difficult and hence the part is inspected for critical areas for which an approximation is possible. In this investigation it was found that the material has better formability at 150^0C. This indicates that at low heating temperature it has better formability than at higher temperature. This is because near 300^0C and beyond dynamic strain regime starts appearing in the material in which material fails like brittle fracture [5]. Fig.2 represents the load Vs displacement graphs recorded during forming of material at various temperatures for 65mm diameter blanks. It can be observed from the Fig.2 that as the temperature increases the punch load is decreasing. This is due to decrease in the mean flow stresses at elevated temperature. From the graph it can be seen that at room temperature the circular blank requires around 23KN of load and to draw the same diameter blank requires around 18KN at 150^0C and it requires around 10KN of load at 300^0C. The safe blank size can be determined by analyzing the thickness distribution for various sizes of blank (Fig. 3). It is also observed from Fig.3 that thickness in the drawn cup is more uniform at higher temperature. This is because to draw the same diameter lower punch loads will be required at higher temperature, this will decreases the necking. As discussed before that by increase in temperature mean flow stress decreases, so the forming force will also decrease. Hence the thickness is expected to be more uniform in the drawn cup at higher temperature. This phenomenon can be clearly seen in Fig.3(a) to Fig(c). By increase in the blank diameter there is an increase in the extent of necking at the punch corner but by increasing in the temperature there is decrease in the extent of necking and the thicknesses are more uniform throughout the cup. From Fig.3(d) it can be observed that by increasing temperature for same blank diameter i.e. 65mm, the thickness is more uniform. At 300^0C (Fig.3(c)) it is observed that the thickness is heterogeneous, it is due to dynamic strain regime [9, 10] that appears in the material beyond this temperature. At this intermediate temperature there is no substantial amount of martensite formation in the material and there in an increase in the work hardening exponent. That is the possible cause of increase in the formability of material [11].

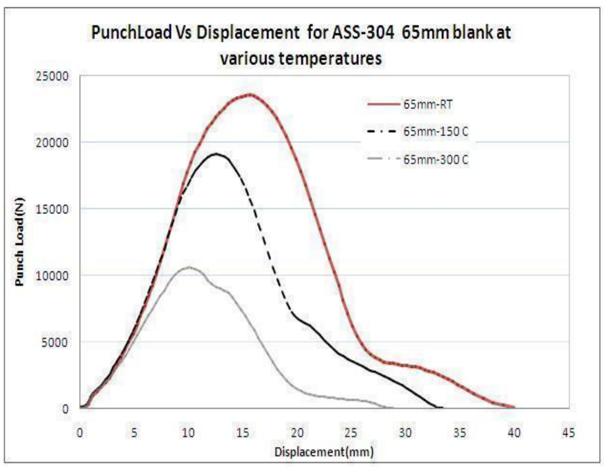

Fig. 2 Punch load Vs Displacement for ASS-304 for 65 mm Blank Diameter at Various Temperature

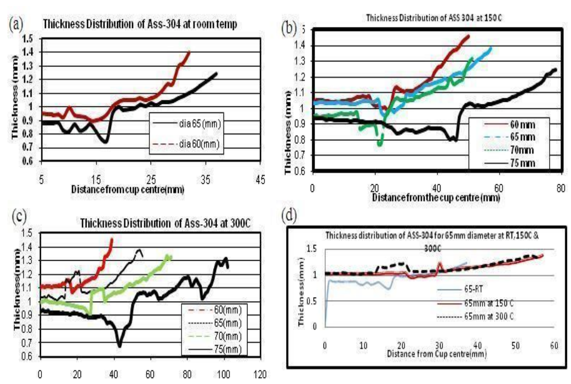

Fig. 3 Thickness Distribution of ASS-304 for Different Diameter at (a) Room Temp (b) 150^0 C (c) 300^0 C and 65 mm Diameter at Various Temp

As explained above in this investigation, a mould was prepared to see the microhardness along the thickness direction of the drawn cup. At all the temperatures i.e RT, 150^0C, 300^0C, microhardness was measured at cup bottom, neck and in the wall region as tabulated in Fig.4. It is observed from all the microhardness graphs (Fig.4) that as the diameter of the blank increases, there is an increase in microhardness due to increase in the plastic deformation which results in work hardening of the cup wall. Through observation for LDR cup at room temperature for 65mm blank diameter (fig.4(a)), the hardness increases in the wall region due to excessive tensile and compressive hoop stresses. But at 150^0C as the blank size increases the hardness is uniformly increased from cup bottom to wall region, at higher temperatures there will be some stress reliving, the microhardness is expected to be lower especially at 300^0C (fig.3(c)). Beyond 300^0C the microhardness is further expected to increase in the drawn cup due to appearance of dynamic strain regime.

Deep drawn cup region	VHN-Hardness number for ASS-304 at Room temperature			
	60mm	65mm		
Bottom	201	389		
Neck	309	260		
Wall	228	326		

Deep drawn cup region	VHN-Hardness number for ASS-304 at 150^0C			
	60mm	65mm	70mm	75mm
Bottom	225	401	350	264
Neck	236	254	343	206
Wall	361	378	336	366

Deep drawn cup region	VHN-Hardness number for ASS-304 at 300^0C			
	60mm	65mm	70mm	75mm
Bottom	201	389	350	227
Neck	309	260	336	322
Wall	228	326	228	305

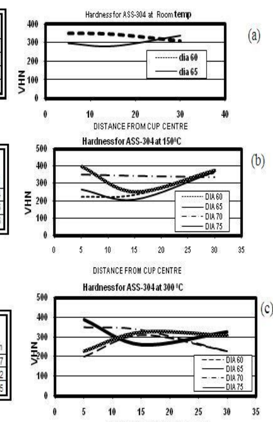

Fig. 4 VHN-Hardness Number for ASS-304 for Different Bank Diameters at Various Temperatures

4. Conclusions

Austenitic stainless steel shows better formability in deep drawing setup at elevated temperatures. Investigation showed that ASS-304 material has better formability at 150^0C as compared to 300^0C due to onset of dynamic strain regime which also depends upon the strain rate (Punch velocity in case of metal forming). Better qualities of cups were formed at 150^0C in terms of uniform thickness distribution in the deformed part. It was also observed that, by increasing the temperature the microhardness decreases at the cup bottom, but in the cup wall the microhardness is a function of blank diameter (extent of deformation) and temperature.

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