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Construction of Forming Limit Diagram for Austenitic Stainless Steel 304 at 150oC

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Abstract— Forming limit diagrams (FLDs) are constructed to describe the strain rates at which a highly localized zone of thinning or necking becomes visible in the surface of sheet metal. Austenitic Stainless Steel 304 is used in nuclear industries specifically to make heat exchangers and different parts of core. The previous research carried out is focuses on the formability study of ASS 304 in deep drawing set-up but to study the entire formability history we need to construct FLD. In this investigation we plan to construct forming limit diagram at 1500c and punch speed of 30 and 50mm/min.In ASS, austenite will convert into some other microstructure either due to change in temperature or due to change in strain rate. So in the present investigation the effect of strain rate on formability studied at temperature 1500c

Index Terms— ASS 304, Forming limit diagram, Formability, Biaxial strain.

I. INTRODUCTION

Austenitic stainless steel 304 (ASS 304) has become workhorse material by the industries and also as the structural material [1]. Forming processes are commonly used in the industry because it eradicates costly operations such as welding, machining and manufactures parts with reduced weight and good mechanical properties with high production rates [2]. In thin sheet metal forming operation, a sheet is deformed by using a punch through a die and to get a desired shape before and after fracture occurs. Factors like mechanical properties , blank size, die and punch radius , blank holding force, punch speed, punch displacement etc, will contributes the success or failure of the component .

In warm forming (stretching at high temperature), the deformed grains recrystallize into smaller grains. Wouters et al investigated the failure analysis of steels and illustrated the different fracture types.

J.Z. Lu et al investigated that the ultimate tensile strength and flow stress of ASS304 stainless steel are strongly dependent of the strain rate during the tensile loading and they increase with increasing strain rate. Forming of the material is affected by various factors like thickness of sheet, forming speed, lubrication condition, temperature, anisotropy and strain hardening.

The composition of ASS304 is shown in Table 1. The property of ASS 304 is due to the presence of molybdenum which prevents chloride corrosion. It also has a low carbon content due to which the wear and friction properties are improved. Hence 304 stainless steel sheets are particularly useful in nuclear reactors as it is used for the purpose of cladding of fuel rods. The reactors temperatures are usually very high. Hence it become imperative to study the material behavior and its properties at elevated temperature.

In aspects of all this still so much research and investigation is required for better usage of Austenitic stainless steels 304 at elevated temperature for best application.

II. EXPERIMENTAL SETUP AND METHODOLOGY

In this investigation, 1 mm thickness sheet of ASS304 is used. In this punching operation is done on a 40 T capacity single action hydraulic press as shown in fig 1.

Fig-1 Experimental test rig

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The sheets of ASS304 are heated to a temperature of 150oc with the help of induction furnace as shown in fig 2. The reason behind the heating of sheets is the properties of ASS304 changes with temperature. Depending upon the temperature austenitic will convert into some other microstructure.

Fig- 2 Induction Furnace

In this grid marking on sheets is done by electro-chemical etching process. In this process a non- contacting grid of 5mm diameter circles is used. This is a hit or trial method, in this first we deform the sheets so that the fracture takes place in it and note down the displacement of the punch by using the attached system . In the next step we try to stop the punch before the fractured displacement of last sheet to get the necking and safe region in sheets.

Three different strain rates like tension- compression, plane strain, tension- tension are occurred during stretching of sheets by varying the width of samples between 20 to 110mm insteps of 20mm. To restrict the material flow from outside a 72mm diameter draw bead is provided on the die.

In this test was conducted with two different punch speed of 30mm/min and 50mm/min. The reason behind different speeds is as speed changes the loading condition changes from gradually increasing load to sudden increasing load. Because of punching operation the circles of ASS 304 sheets will convert into ellipses. Measure the minor diameter and major diameter of the ellipses in both transverse and longitudinal direction of the sheet samples by using travelling microscope.

TABLE 1
MATERIAL COMPOSITION FOR ASS- 304 (%WT)

Element	*Fe*	*Mn*	*C*	*Mo*	*Co*	*Si*	*Cr*	*Ni*	*Cu*	*Others*
ASS 304	70.780	1.140	0.025	0.360	0.210	0.410	18.400	8.190	0.180	0.305

TABLE 2
MATERIAL PROPERTIES OF ASS 304 AT VARIOUS TEMPERATURES

Temp. (^{0}C)	E (GPa)	K (MPa)	N	R_0	R_{45}	R_{90}
Room Temp.	203	1414	0.387	0.87	1.24	1.08
150^{0}C	167	1299	0.435	0.64	2.24	1.16
300^{0}C	141	1136	0.458	0.91	1.24	0.68

For each sample take the diameter values for three to four ellipses in fractured region and safe region to get the maximum number of data points.

Forming limit diagram is a representation of the critical combination of the two principal surface major strains and minor strains which localized necking instability is observed. When the strain ratio is positive (minor strain is positive), stretching is observed. In case of negative strain (minor strain is negative) one can conclude drawing is observed.

III. RESULT AND DISCUSSION

The sheets of ASS 304 with different width are shown in fig-3. The fractured specimens after punching or stretching operation are shown in fig-4. It is difficult to draw a very precise curve that indicates the onset of failure because of the large scatter in the measured strains with varying blank width and also due to the overlap of some points. The forming limit curves are shown in fig-5 and fig-6 for punch speed of 50mm/min and 30mm/min respectively separating the fractured , necked and safe region.

Figure 5 & 6 show the forming limit diagrams of all coated and uncoated steel sheets. The area below the lower line of the band is the safe working zone for the sheets of all possible combinations of strains. Above the upper line of the band, the sheet metal is certain to fail by necking/fracture. The area within the band represents the critical region where the sheet is likely to develop the

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necking/onset of failure. The forming limit diagram was constructed using strain values obtained from the specimens with varying width and some of the data points were omitted for clarity

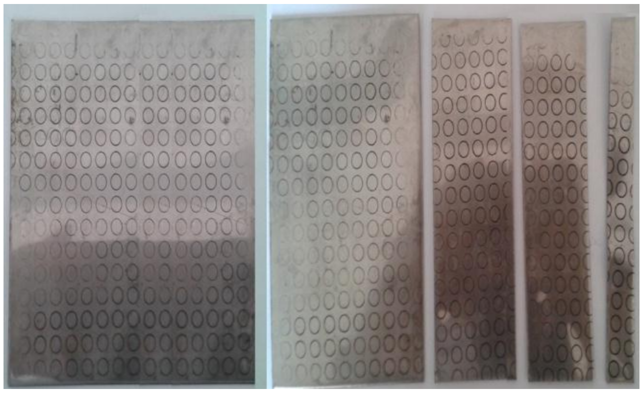

Fig-3 ASS 304 Sheets with circular grid

Fig-4 Fracture in the specimens

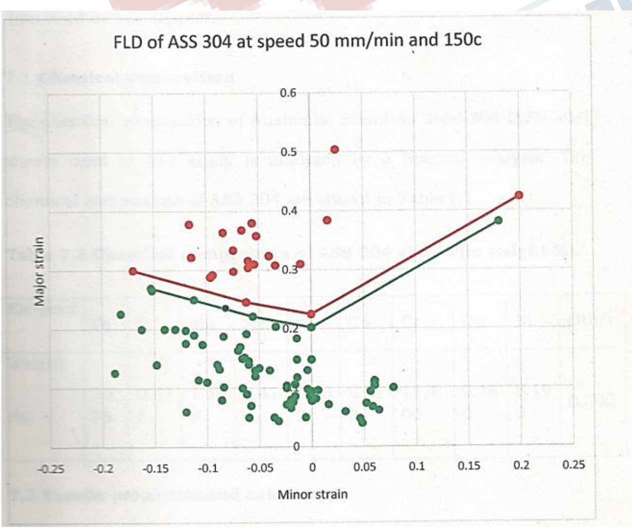

Fig-5 FLD at 50mm/min

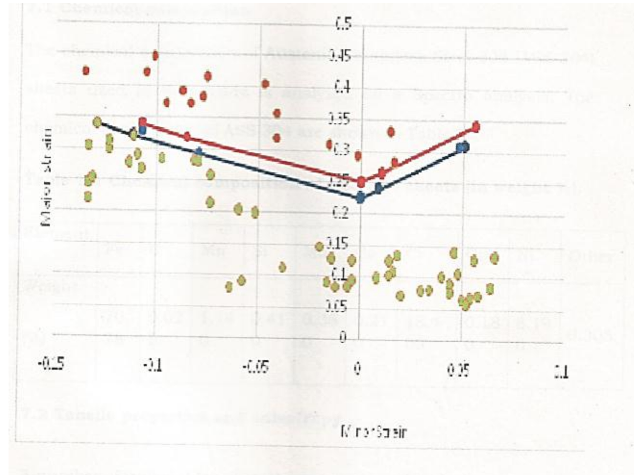

Fig-6 FLD at 30mm/min

IV.CONCLUSIONS

In this study, formability limit diagram of ASS 304 was constructed at 150o and at punch speeds of 50mm/min and 30mm/min. Since at higher punch speed, the tendency of austenite converting into martensite will be more, it was thus observed in FLD's that for higher punch speed bi-axial tension and tension-compression region lines are having a downward trend i.e., fracture is predominant.

V. FUTURE SCOPE

Since ASS304 is sensitive to both temperature and deformation speed, construction of similar FLD are required to be plotted at different temperatures, keeping the punch speed at 50mm/min and 30mm/min respectively, so that a 3D FLD can be constructed with Z axis either being temperature or deformation speed.

VI. REFERENCES

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