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On the Strain Hardening Exponent During Tensile Testing of ASS 304 Steel Sheets at Elevated Temperatures

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Abstract: Formability of metallic materials is generally assed by the material properties such as strain hardening exponent (n) and planar/normal anisotropy. In this work, strain hardening behavior has been studied between the room temperature and elevated temperature tensile tests of ASS 304 steel specimens. Anisotropy values were determined as per ASTM E517 standard along three directions: 0°, 90° and 45° to the rolling direction. Tensile tests were conducted from room temperature to 300°C at an interval of 100°C. Strain hardening exponent values also showed the higher values for 300°C temperature specimen compared to other temperatures. Finite element analysis of the tensile deformation was also studied.

Keywords: Strain hardening exponent, anisotropy, yield strength, finite element analysis.

I. INTRODUCTION

Sheet metal forming is an industrially important technology since many decades, in the production of thin sheet metal parts at minimum cost. The hot-rolled or cold rolled thin sheets have many applications in kitchen utensils, building products, automobiles, aviation, food and dairy industries. The plastic strain ratio (r) is an index to show the ability of a sheet material to resist thinning or thickening**.** The 'r'-value is a measure of sheet metal draw ability [1]. During plastic deformation the strain hardening exponent determines how metal behaves when it is being formed. It actually measures the increase in hardness and strength caused by plastic deformation [2]. Generally, higher the strain hardening exponent (n) and plastic strain ratio (r) better will be the formability of materials. This was observed during the study of three different sheets namely HSLA, C-Mn and micro alloyed [3]. Effect of anisotropy values during forming and right way of selecting 'r' values for different sheet metal forming processes was investigated by [4]. In another study of the tensile deformation behavior of IN 718 super alloy at 650°C at different strain rates it was proved that effect of strain hardening exponent and strain rate should be taken into account during deformation modelling [5]. However, the forming behavior of stainless steel sheets during hot forming is still uncharted to a greater extent. In this current work, efforts have been made to understand the strain hardening characteristics during tensile testing of ASS 304 at elevated temperatures from 100°C-300°C with test interval of 100°C. Finite element simulation was also carried out using ABACUS software.

II. MATERIAL AND METHODOLOGY

Cold rolled austenitic stainless steel 304 sheet of 1 mm thickness was selected for this research work. Table I. shows the chemical composition of the material. Tensile tests at room temperature were performed as per ASTM E8M [6] standard and hot tensile tests were conducted as per ASTM E21 [7] standards. The strength coefficient (K) and strain hardening exponent (n) data were calculated using power law as given in eq.(1).

$$\sigma = K \in^{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Table. I Weight % chemical composition of ASS-304.

Elements	C	Mn	Si	P	S	Cr	Ni	N
% wt	18.4	1.43	0.36	0.01	0.002	0.01	0.05	8.28

III. RESULTS AND DISCUSSION

A. Tensile properties: The tensile tested specimens were shown in Fig. 1

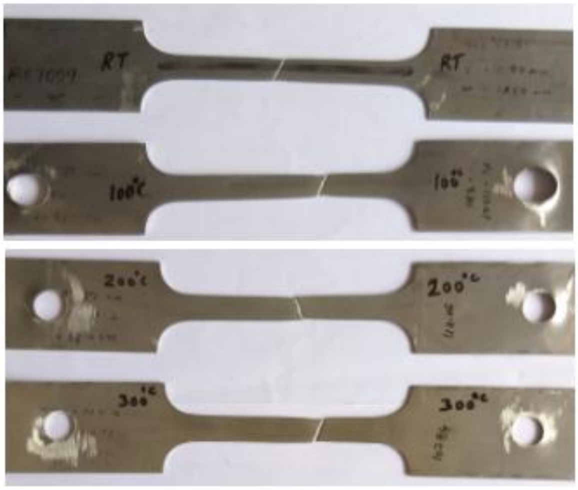

Fig. 1 Tensile test specimens as per ASTM E8 and E21standards.

Table II indicates the base line mechanical properties of ASS-304 steel sheets. High strain hardening exponent value is indicated for 300°C specimen.

Table. II Mechanical properties of ASS304.

Temperature	YS(MPa)	UTS(MPa)	Strain hardening exponent (n)
RT (26°C)	314.06	726.29	0.2442
100°C	117.68	566.15	0.2549
200°C	180.71	473.61	0.3113
300°C	430.19	446.39	0.3868

B. Strain hardening behaviour: After conducting tensile tests at room temperature and at elevated temperatures, the strain hardening behaviour studied is shown in Fig. 2

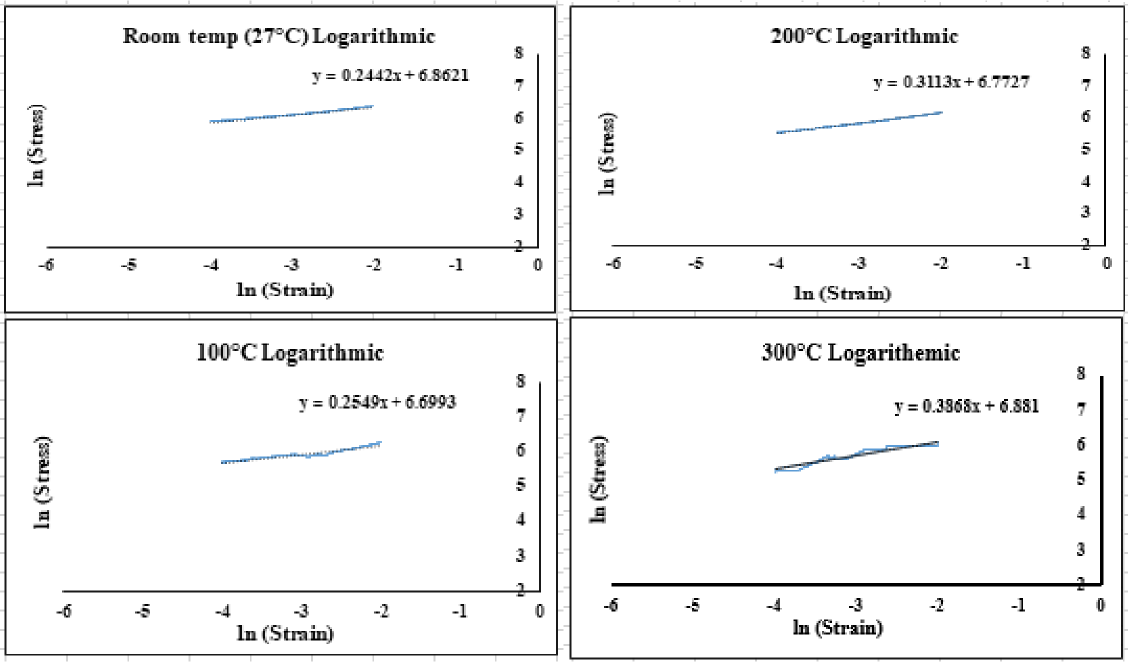

Fig. 2 Behaviour of strain hardening at different temperatures

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C. Finite element analysis: Finite element analysis of the tensile test was carried out using ABACUS software. The explicit analysis of ASS-304 specimen under tensile loading was simulated using shell elements as shown in Fig. 3.

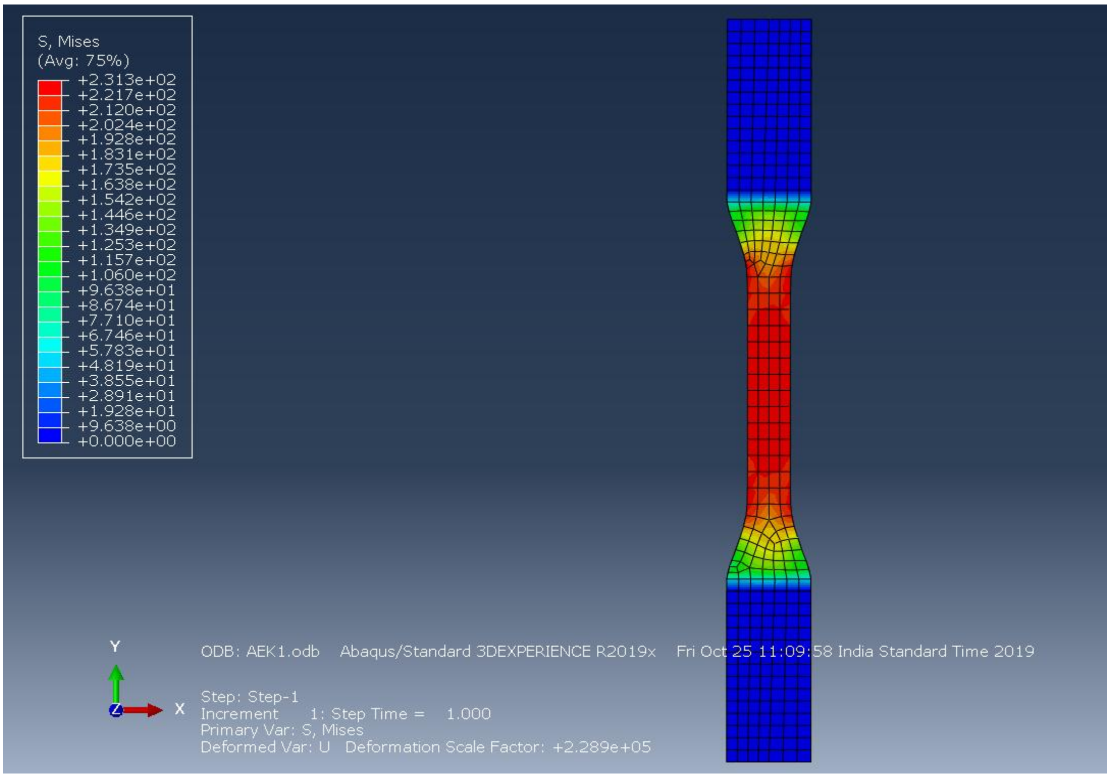

Fig.3 Stresses in tensile specimen

IV. CONCLUSION

In this work the strain hardening behaviour of ASS-304 is studied by subjecting the specimens to tensile tests at room temperature and elevated temperatures. Following conclusions were drawn

- The average strain hardening exponent (n = 0.3868) is found to be higher for 300°C specimen.
- UTS is gradually decreasing from room temperature specimen to 300°C specimen.

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