Sensitization of Austenitic Stainless Steel and it's Effect to Ultrasonic Velocity and Hardness

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ABSTRACT

Microstructural examination was used for the analysis of sensitization. Ultrasonic Non destructive technique is the suitable method for microscopic examination. Based on this, this work aims to evaluate the performance of microstructures of austenitic stainless steel in ultrasonic velocity and hardness. The sample which was heat treated at 1200°C is considered as the sensitized sample. In the sensitized sample ultrasonic velocity dominates the grain size. Hardness increases with sensitization.

Key words: Non-destructive technique, microstructure, sensitization, Ultrasonic velocity, Hardness.

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1.INTRODUCTION

Due to the superior mechanical properties relative to other structural steels, Stainless steel are becoming attractive to a number of industry sectors[1]. The classifications of the available grades of Stainless steel are ferritic, Martensitic, austenitic, duplex and precipitation hardenable[2]. Industries such as power, chemical, petrochemical are using Austenitic stainless steel. These steel exhibit excellent resistance to general corrosion, adequate mechanical properties and good fabricability. Chromium carbides which are formed due to the interactions of carbon and chromium atoms were suggested to be relevant mechanism in the case of austenitic stainless steel.[3].Sensitization occurs due to the contribution of Chromium carbides. The wide application of austenitic stainless steel in industry is affected by the sensitization phenomena. Microstructural examination was used for the analysis of the sensitization development. Microstructural details reveals the history of mechanical and heat treatments given to the material. The valuable information about the microstructures and the mechanical properties can be provided by Ultrasonic Non destructive technique[4]. Ultrasonic Testing is regarded as the most popular non-destructive testing method[5]. Low intensity ultrasound waves are applied in ultrasonic nondestructive evaluation to test objects without creating any damage[6]. On the basis of modes of vibration of the particles of the medium, Ultrasonic waves are classified as longitudinal, shear surface and lamb waves[7]. In ultrasonic testing the most widely used wave is the longitudinal wave. Longitudinal wave originates all the energy needed for testing the materials. Ultrasonic velocity has find a wide range of application in the field of material characterization. They are used for evaluation of mechanical properties and elastic moduli of many engineering material[8]. Number of studies are being done to correlate ultrasonic velocity with microstructural features [9-13].The main objective of this paper is to evaluate the performance of microstructures of AISI 316 Grade Austenitic stainless steel in ultrasonic velocity and hardness.

2. MATERIALS AND METHODS

Austenitic stainless steel in the form of 3 mm thick sheet was cut into 6 pieces of 1 cm length, 1cm breadth, and 3 mm thickness, and these specimens were given different heat treatments in the range of 1000^0C to 1200^0C with an increase of 50^oC for 15 minutes holding time in an Electrical muffle furnace followed by water quenching. No special protective environment was employed during heat treatment.

Microstructural examination was done by METSCOPE-I microscope. Ultrasonic testing was done by contact pulse-echo method in an Olympus parametric NDT model. By measuring the time taken by the ultrasonic waves to travel the thickness of the material between the parallel faces, ultrasonic velocity was determined. and can be estimated from the relationship

Velocity (m/s) = 2 x Thickness (m) / time(s)

Density of the samples were determined by density apparatus that works on the principle of Archimedes. Density Ultrasonic longitudinal velocities and Ultrasonic shear wave velocities were used to calculate Young's modulus, Bulk modulus, shear modulus and Poisson's Ratio from the relations given as follows[14]

$$E = [\rho\, Vs^2 (3V_L^2 - 4V_S^2)] / (V_L^2 - V_S^2)$$
$$G = \rho V_S^2$$
$$K = \rho\, (3V_L^2 - 4V_S^2) / 3$$
$$\nu = (V_L^2 - 2V_S^2)/[2\, (V_L^2 - V_S^2)]$$

Where E is the Young's modulus, K is the bulk modulus, G is the shear modulus, ν is the Poisson's ratio, L is the longitudinal modulus and ρ is the density. Vicker's hardness tester is used for the estimation of hardness.

3. RESULTS AND DISCUSSION

The change in microstructure of the AISI 316 Grade Austenitic stainless steel due to the various heat treatment, and the performance of microstructure in ultrasonic velocity and Hardness have been discussed.

3.1 Microstructural analysis

The results of microstructural examination are depicted in fig 1.

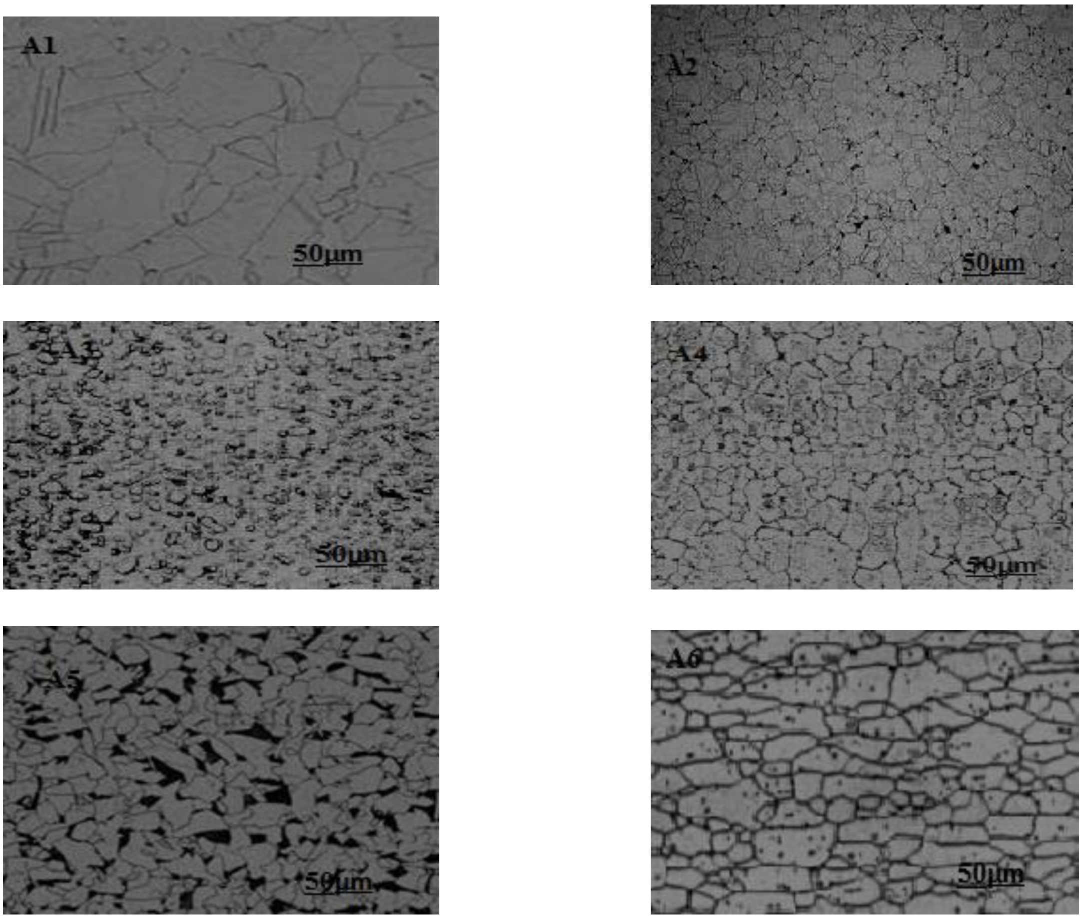

Fig.1.Microstructure of AISI 316 grade Austenitic Stainless steel heat treated for different temperatures.A1(Received condition), A2(1000^{o}C for 15 min) A3(1050^{o}C for 15 min), A4(1100^{o}C for 15 min), A5(1150^{O}C for 15 min), A6(1200^{o}C for 15 min)

Heat input and cooling rate are the two factors that affects the microstructure of austenitic stainless steel[15]. From the fig we found that the there is no precipitation for specimen in the received condition.[A1] At elevated temperatures typically between 450^{o}C to 850^{o}C the major problem in Austenitic stainless steel is caused due to the precipitation of chromium carbides at the grain boundaries. Due to the diffusional reaction of Chromium carbide, there is depletion of Cr in the austenitic solid solution. This reduces the formation of Cr_2O_3 passive layer, and unable to make stainless effective[16]. Sample A1 is considered as unsensitized. When the sample is heated to 1000^{o}C for 15 min there is little bit of sensitization, this is due to the slow diffusion of carbon and even slow diffusion of chromium and this is observed in (A2). Grain boundaries provides excellent nucleation sites hence precipitation of Chromium carbides occurs at grain boundaries. This is observed in A3.Fig A4 reveals that aging at 1100^{o}C leads to the increase in precipitation. From A5 we observe that the carbides have grown to bigger size. Fig A6 shows the ditch structure in which the grains are completely surrounded by the precipitation with larger size. The sample is considered to be free from sensitization if it shows the step or dual structure whereas it is considered to be sensitized if ditch structure is observed.

3.2 Effect of microstructure in ultrasonic velocity and Hardness

The ultrasonic velocity and hardness of the heat treated samples are given in Table 1.

Table.1 Ultrasonic velocity and hardness of AISI 316 grade Austenitic stainless steel at different temperature.

Specimen	HeatTreatment	Longitudinal Velocity (m/s)	Microhardness (VHN)
D1	None	5906	194
D2	1000^{o}C	6043	156
D3	1050^{o}C	5967	208
D4	1100^{o}C	5928	160
D5	1150^{o}C	5916	173
D6	1200^{o}C	5963	178

The Ultrasonic velocity as shown in the fig.2 increases at the beginning and decreases with an increase of temperature up to 1150^{o}C. With a rise of 50^{o}C ultrasonic velocity was found to increase. The increase in ultrasonic velocity is due to the precipitation of carbides. Several studies indicate that due to the precipitation of carbides ultrasonic velocity increases[17]. This is seen from fig.1(A2). The decrease may be due to the increase of grain size. Even though there is a precipitation of carbides in the grain boundaries ultrasonic velocity decreases. This is observed in A3, A4 and A5. At 1200^{o}C Ultrasonic velocity increases (A6). In this case ultrasonic velocity dominates the grain size.

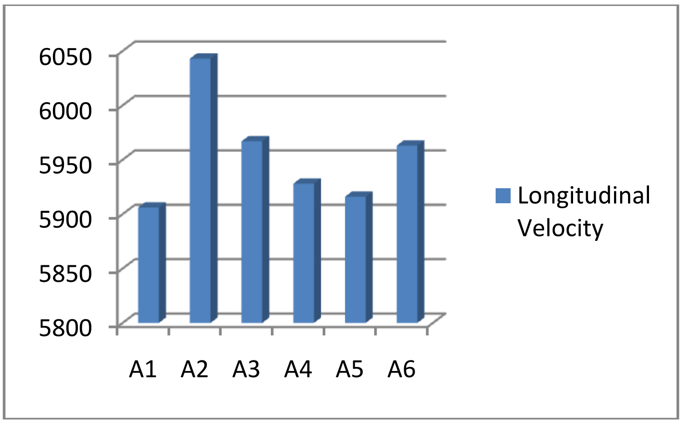

Fig.2.The variation of Ultrasonic velocity with microstructure

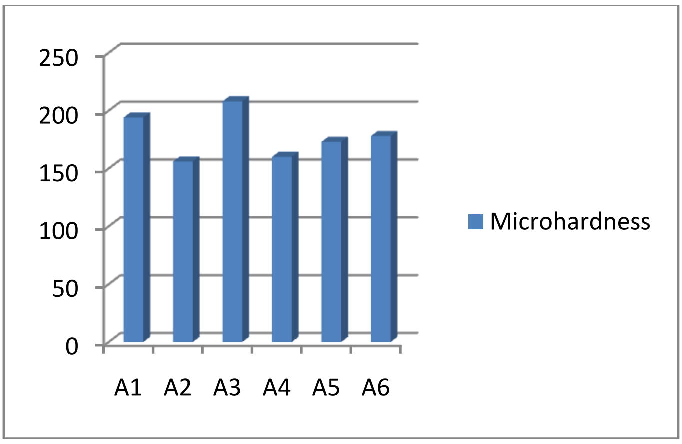

Fig.3.The variation of hardness with microstructure

Depending on the compositions there may be different effect of hardness with increase of temperature. It is observed from the fig3 that there is rise and fall of hardness value till A4. After A4 there is continuous increase of hardness value. In our results we obtain the highest hardness value for the sample A3. Chromium carbide has the major contribution to the hardness of stainless steel. The possible nucleation sites for Chromium carbide precipitation becomes less due to the presence of copper. This results in improvement of resistance to sensitization. The microstructure of the sample A3 reveals that the influence of copper is effective against precipitation Hardness decreases with sensitization[18] In our case hardness increases with sensitization. This is similar to the results of S. A. Tukur [19].

CONCLUSION

The effect of heat treatment on the evolution of microstructure and the perfomance of microstructure in ultrasonic velocity and hardness of Austenitic stainless steel was investigated. The Conclusions are summarized as follows.

1. Sensitization was observed at 1200^{o}C for 15 min holding time.
2. The increase of ultrasonic velocity in the sensitized sample reveals that Ultrasonic velocity dominates the grain size.
3. Hardness increases with sensitization.

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