Elastic Property of Duplex Stainless Steel using Ultrasonic Velocity

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Abstract— Elastic constants of duplex stainless steel and its effect with temperature were determined by measuring ultrasonic velocity. The sample which was heat treated at 11000C plays a dominant role it exhibits a large values of elastic constants. The correlation of ultrasonic velocity with elastic constants reveals that both ultrasonic longitudinal velocity and ultrasonic shear wave velocity are required for material characterization.

Key words: Elastic Constants, Ultrasonic Characterization, Duplex, Stainless Steel

I. Introduction

Elastic constants find tremendous use in material characterization. Excellent structural design parameter is the factor we get from the ratios of elastic modulus to density or to thermal conductivity. As Elastic constants relate intimately to both the inter atomic potential and the lattice vibration spectrum, many fundamental solid state phenomenon such as diffusion, theoretical strength, and lattice defect energies are related in terms of Elastic constants. The physical properties of the materials such as Young's modulus ,bulk modulus ,shear modulus and poisson's ratio are very useful in characterizing and comparing materials and for detecting changes in material properties.[1]. The qualitative and quantitative evaluation of physical and elastic properties of materials can be determined by ultrasonic techniques.[2]. Determination of the material properties without harming is the significance of ultrasonic technique.[3]. In recent years duplex stainless steel finds applications in various fields like chemical plant oil and gas production and transportation, offshore drilling and pipeline application due to the properties such as higher strength, better corrosion resistance, and improved resistance to stress corrosion cracking.[4,5,]. Knowledge of the elastic properties is very important to determine the mechanical behaviour, e.g strength ,hardness and fracture toughness, and also control the response of the material to shock or impact[6].

In this study we examine the elastic properties of duplex stainless steel at different temperature for 15 min holding time. In our experiment we used pulse echo method to characterize the elastic constants of the materials through detection of ultrasonic waves. Elastic constants are calculated from ultrasonic longitudinal and shear wave velocities. And the elastic constants is directly linked with ultrasonic velocities[7,8].

II. Materials and Methods

The chemical composition of SAF 2205 duplex stainless steel is shown in table.1.

	C	S	P	Si	Mn	Cr	Ni	Mo	N
Wt%	0.02	0.02	0.03	0.6	1.4	22.2	5.9	2.9	0.15

Table 1: Material

The samples were cut into 6 pieces in the form of 50 mm length 50 mm breadth and 5mm thickness. The samples to be tested were heated in a muffle furnace at 1000°C, 1050°C, 1100°C, 1150°C and 1200°C for 15 min followed by water quenching. Ultrasonic velocity measurements were performed by measuring the time of flight measurements using a contact pulse echo method and can be estimated from the relationship velocity = 2 ×thickness/time.

Ultrasonic velocity measurement was done by the contact pulse echo method in an Olympus panametrics NDT model 5800 unit using both longitudinal and shear wave probe at room temperature .The elastic constants are calculated from ultrasonic longitudinal and shear wave velocity. To find the elastic constants the other factor required is the density of the material.[9].After the calculation of density(ρ) of all the samples by Archimedes principle and knowing the values of ultrasonic longitudinal and shear wave velocities ,Elastic constants, Young's modulus(E), Shear modulus(G),Bulk modulus(K) and Poisson's Ratio(σ) can be determined from the relations given as follows.

$$E = (1+\sigma)2G \quad (2.1)$$

$$G = V_S^2\rho \quad (2.2)$$

$$K = L - (4/3)G \quad (2.3)$$

$$\sigma = (L - 2G) / 2(L - G) \quad 2.4)$$

III. Results and Discussion

Elastic constants for Duplex stainless samples under analysis were obtained from the velocities of ultrasound. These results are summarized in Table 2.

Specimen	Young's Modulus (GPa)	Shear Modulus (GPa)	Bulk Modulus (GPa)	Poisson's Ratio
D1	194.7	77.9	130.2	0.25
D2	194.5	77.8	130.1	0.25
D3	194.0	77.6	130.0	0.25
D4	256.2	85.4	144.3	0.50
D5	187.8	75.1	127.8	0.25
D6	193.7	77.5	132.9	0.25

Table 2: Elastic constants of heat treated samples of Duplex stainless steel.

D1,D2,D3,D4,D5,D6 represents the samples which was as in received condition, and heat treated at the temperatures of 1000°C,1050°C,1100°C,1150°C,1200°C for 15 min holding time.

Young's modulus and shear modulus for the samples D1 to D4is higher than that of D5 and D6. Bulk modulus for the sample D4 is higher than all other samples.

With further increase of temperature Bulk modulus decreases and then increases. Poisson's ratio is same for all the samples except D4. The sample which was heated at temperature 1100^{o}C plays a dominant role and it has the higher elastic constants. It is clear from our observation that when DSS is heated to a temperature of about 1100^{o}C exhibits large elastic constants. The variation in Young's modulus, shear modulus, Bulk modulus, and poisson's ratio of heat treated DSS at different temperature are shown in figure.

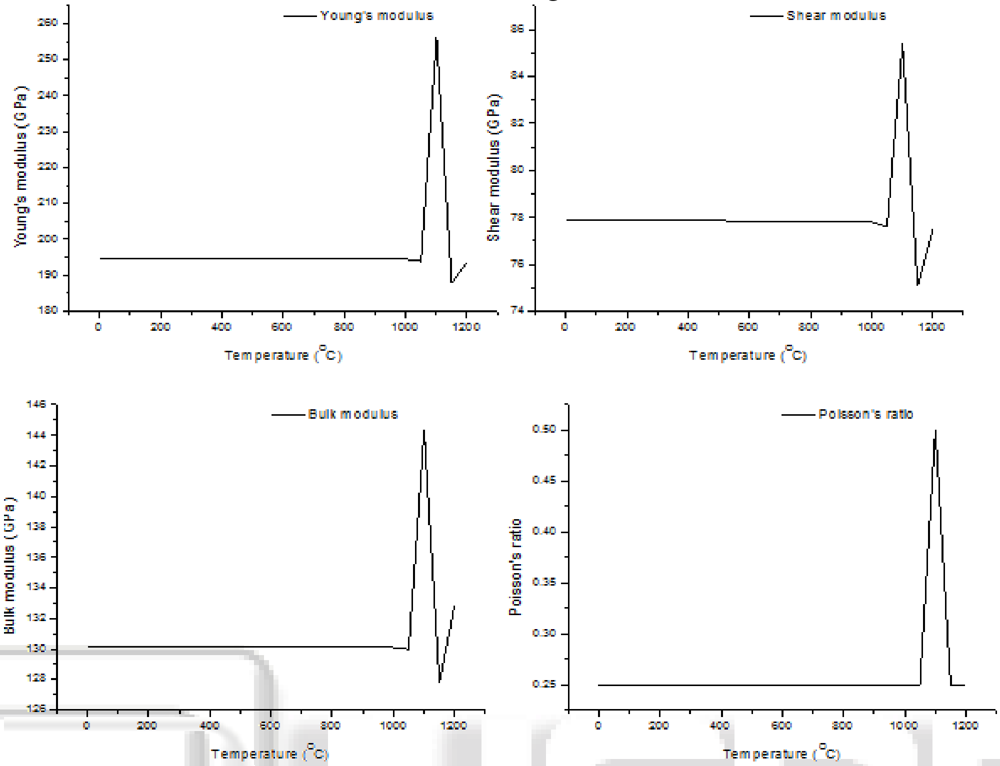

Fig. 1: Variation in young's modulus, shear modulus, bulk modulus, poisson's ratio of DSS heat treated at different temperatures.

The relationship between Ultrasonic wave velocity, and elastic constants were studied for the DSS specimens the variation of ultrasonic wave velocity with the elastic constants were shown from Fig 2 to fig 5.

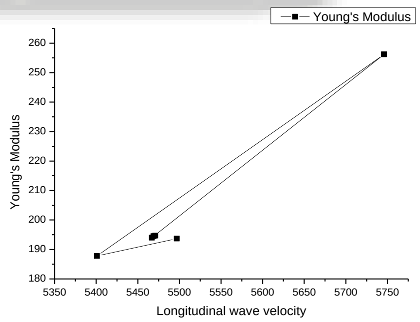

Fig. 2: Correlation between longitudinal wave velocity and Young's modulus.

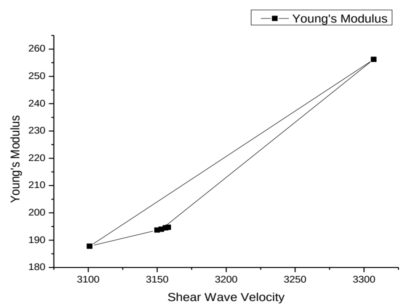

Fig. 3: Correlation between shear wave velocity and Young's modulus.

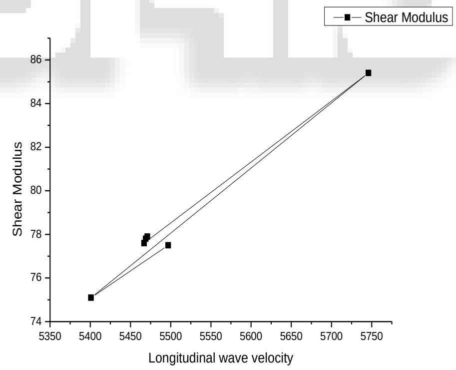

Fig. 4: Correlation between longitudinal wave velocity and shear modulus.

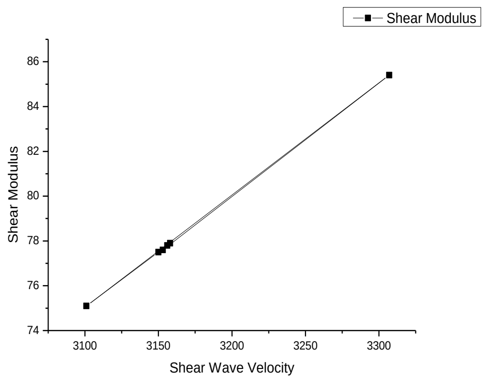

Fig. 5: Correlation between shear wave velocity and shear modulus.

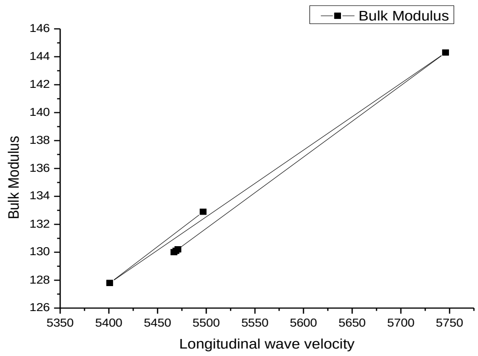

Fig. 6: Correlation between longitudinal wave velocity and Bulk modulus.

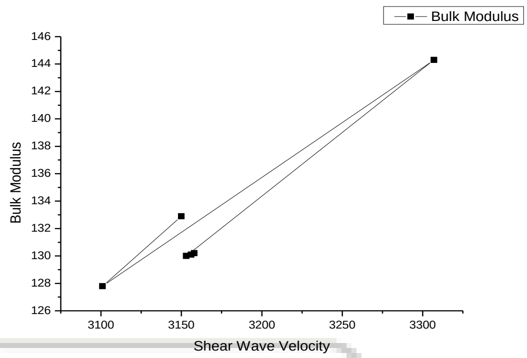

Fig. 7: Correlation between shear wave velocity and Bulk modulus.

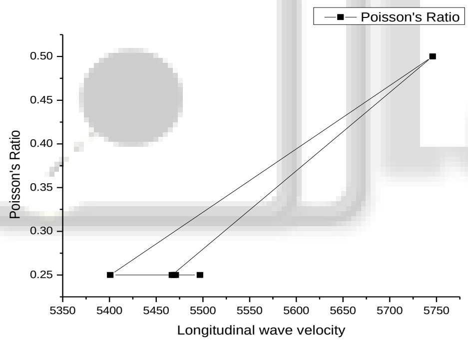

Fig. 8: Correlation between longitudinal wave velocity and Poisson's Ratio

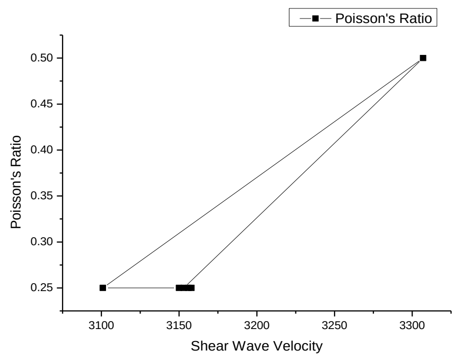

Fig. 9: Correlation between shear wave velocity and Poisson's

IV. CONCLUSION

From the present investigations following are the conclusions. Ultrasonic testing values give more or less accurate values and the studied samples showed good results. The inter atomic forces in the sample D4 is higher than the remaining ones, since it has higher value of young's modulus. The poisson's ratio obtained lies within the permissible region [0.0-0.5] and hence all the samples are metallic in nature. The correlation studies on ultrasonic longitudinal and shear wave velocity with elastic constants indicate that both longitudinal and shear wave velocity can be used for material characterization This was contrary to the results of Anish kumar et.al that shear wave velocity shows better correlation than longitudinal velocity [10].The variation in the correlation is due to the change in internal structure of the material due to the heat treatment. The present experiment finds a solution for the characterization of the materials as a function of temperature.

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