IJIRSET

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Ultrasonic Characterisation of Heat Treated Tungsten Alloys used for TIG welding

Bernice Victoria D.C. [1], Dr. Gene George [2], Kevin Ark Kumar [3], Dr. Anto Bennet M. [4]

Research Scholar, Department of Physics, T.B.M.L. College, Porayar, Tamilnadu, India[1]

Associate Professor, Department of Physics, T.B.M.L. College, Porayar, Tamilnadu, India[2]

Senior Engineer, Bharat Heavy Electricals Limited (BHEL), Tiruchirappalli, Tamilnadu, India[3]

Professor, Department of ECE, Vel Tech Engg. College, Chennai, Tamilnadu, India[4]

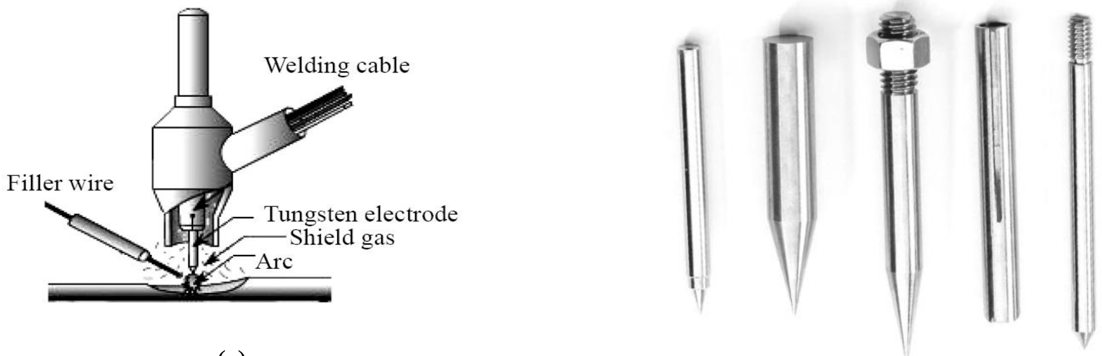
ABSTRACT: Tungsten inert gas (TIG) welding, also called as gas tungsten welding (GTAW), use tungsten electrode for arcing. The tungsten alloy electrode is subjected to various temperature ranges during the welding process based on the welding time, welding current, welding pulse etc. Ultrasonic velocity for tungsten alloy test coupons held at 1500 deg C for 20, 40 and 60 minutes and at 1000 deg C, 1200deg C and 1500 deg C for 40 minutes period , were found to be strongly influenced by the elastic constants. Elastic constants shows better correlation with longitudinal velocity than shear velocity.

KEYWORDS: TIG welding, NDT, Ultrasonic characterization, Tungsten alloy.

I. Introduction

Tungsten inert gas (TIG) welding, also called as gas tungsten welding (GTAW), uses a tungsten electrode for arcing. The tungsten electrode used in this welding process is a non-consumable one, i.e., the negative supply from an arc welding machine will be applied to the tungsten electrode to produce high intensity arc for welding (autogenous weld). Sometimes a filler wire, with relatively lower melting point, will be made to melt in the arc. The weld region is confined from atmospheric contamination by an inert gas (argon or helium), also called as shielding gas. Constant-current welding power source is used to generate energy across the arc through a column of highly ionized gas [1].

TIG welding is generally used to weld sections of stainless steel, alloy steels and non-ferrous metals. TIG welding machines of various capacities and technologies are commonly found in manufacturing industries and aerospace industries. The power plant equipment such as super-heater coils, re-heater coils, economizer coils of high pressure boilers are welded using this process [2]. The TIG process gives greater control over the weld allowing for stronger, higher quality welds than other welding processes such as shielded metal arc welding and gas metal arc welding. The schematic of TIG process is depicted in Fig. 1.a.



(a) (b)

Fig. 1. (a) Schematic of TIG welding Process (b) Variety of tungsten electrodes

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

The electrode used in TIG welding is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3,422 °C (6,192 °F). Except due to some erosion and burn off etc., the electrode is not consumed during welding. Electrodes have a clean finish or a ground finish, making them optimal for heat conduction. The diameter of the electrode can vary between 0.5 and 6.4 mm and their length can range from 75 to 610 mm. Photograph of various tungsten electrodes are shown in fig.1.b

Variety of tungsten alloys electrodes for use in TIG welding process have been standardized by the International Organization for Standardization in ISO 6848 and the American Welding Society in AWS A5.12. Pure tungsten electrodes (WP or EWP) are general purpose and low cost electrodes. However, they have poor heat resistance and electron emission; hence they find limited use in welding of alloys. Hence tungsten alloys are preferred for making electrodes. Tungsten-copper and tungsten-silver combinations are used in large quantities as electrical contact and welding electrode materials. Tungsten-nickel, tungsten-nickel-iron and tungsten molybdenum, combinations have been under intense investigation for missile and atomic energy applications for some years. Alloys of tungsten, nickel, and copper, generally referred to as heavy alloys and are also used as weighting devices, gyro rotors, fly wheels, in radiation shielding, missile systems etc [3].

The material characterization of metals tested at STC will have large variation under various temperatures [4-7]. The tungsten alloy electrode used in TIG welding process is subjected to various temperature ranges based on the welding time, welding current, welding pulse etc. Hence the objective of this paper is to study the characterization of tungsten alloys at different temperatures. Non Destructive Testing methods can offer large potential in evaluation of mechanical properties of these materials. Among the various NDT methods, ultrasonic technique can provide valuable information about the mechanical properties [8-13].Ultrasonic parameters (longitudinal and shear velocity) are also used for evaluation of mechanical properties and elastic moduli of many engineering materials [14, 15].

An experiment on tungsten heavy alloy (Tungsten 90% Nickel 5% and copper5%) was conducted to under the mechanical properties at various temperatures. The alloy is heat treated at 1500degC for 20, 40 and 60 minutes and heat treated at 1000degC, 1200degC and 1500degC for 40 minutes, followed by water quenching. Elastic constants of these heat treated test coupons were estimated from longitudinal and shear wave velocities. The correlation between the ultrasonic velocities and elastic constants was also studied.

Paper is organized as follows. Section II describes the material under study and the experimental procedures. The results obtained from the experiment and detailed discussions are presented in Section III followed by conclusion.

II. MATERIALS AND METHODS

Tungsten alloy in the form of 3mm thick sheet was cut in to coupons of 1cm length 1 cm breadth and 3mm thickness. Test specimens were divided in to two sets. One set of specimens were heated in an Electric muffle furnace to 1500degC and held at this temperature for 20, 40 and 60 minutes followed by water quenching and the other set of specimens were heated at 1000degC, 1200degC and 1500degC for 40minutes followed by water quenching. No special protective environment was employed during heat treatment.

Ultrasonic tests were accomplished by the contact pulse Echo method. Ultrasonic velocity was determined by measuring the time taken for the ultrasonic waves to travel through thickness of the material. Ultrasonic longitudinal and shear wave velocities and density of material were used to calculate the four different Elastic constants Young's modulus (E), Bulk modulus(K), Shear modulus(G) and poisons ratio from the relations given as follows.

$$E = (1 + \sigma)\, 2G \qquad (1)$$

$$K = L - (4/3)G \qquad (2)$$

$$G = V_s^2 \rho \qquad (3)$$

DOI: 10.15680/IJIRSET.2014.0312016

IJIRSET

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

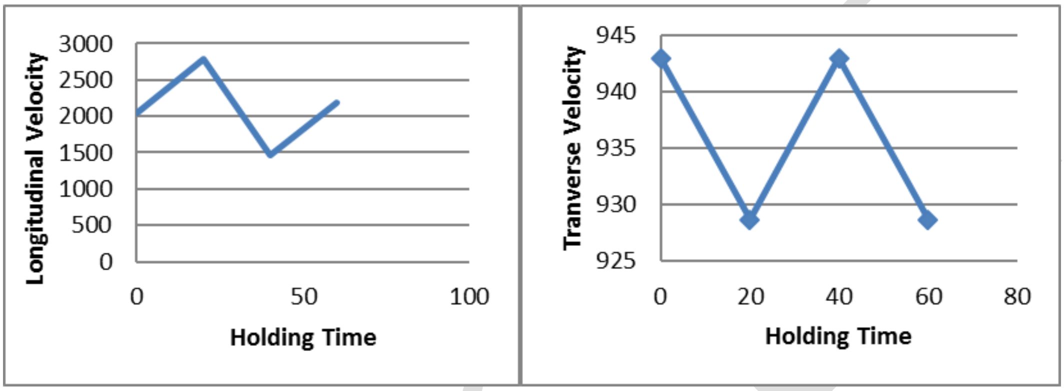
Vol. 3, Issue 12, December 2014

$$\sigma = (L - 2G) / 2(L - G) \qquad (4)$$

Density of the sample was determined using Archimedes principle and this value is used in Elastic constant calculations.

III. Results and Discussions

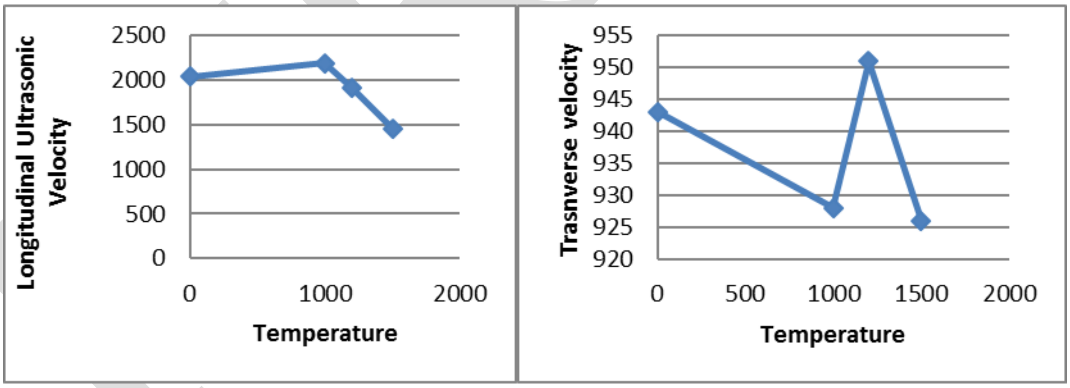
The trend in change in ultrasonic velocity in tungsten alloy heat treated at 1500 deg C for 20, 40 and 60 minutes holding time and at 1000 deg C, 1200 deg C and 1500 deg C for 40minutes are shown in Fig. 2 and Fig. 3.



(a) (b)

Fig.2. (a) Longitudinal velocity vs holding time at 1500 deg C (b) Transverse velocity vs holding time at 1500 deg C

The longitudinal velocity as shown in fig.2.(a) increase in the beginning and decreases and finally increases with the increase in holding time and from the fig.3.(a) we see that the ultrasonic longitudinal velocity increases in the beginning and with increase in temperature it founds to be decreases.



(a) (b)

Fig.3. (a) Longitudinal velocity vs temperature (b) Transverse velocity vs temperature

It has been reported that sound velocity decreases with increase in the grain size causes ultrasonic waves to take a longer path to cover the material thickness and thereby decreases the sound velocity drastically [16, 17]. Therefore initially the sound velocity is expected to decrease Contrary to this sound velocity was found to increase. At one point of time only the effect of grain size on longitudinal velocity dominates and then the longitudinal velocity decreases. Also we infer that even though grain coarsening reduced the velocity, Ultrasonic longitudinal velocity increases at 1200 deg C the effect of grain size on longitudinal velocity dominates and then onwards longitudinal velocity starts decreasing.

DOI: 10.15680/IJIRSET.2014.0312016

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Elastic Constant

Ultrasonic inspection uses high frequency elastic waves to non-destructively inspect the materials. The most frequent application of ultrasonics in material property measurement involves the study of elastic constants and related strength properties [18]. The elastic deformation can be quantified by elasticity and Poisson's ratio. Additionally elastic stiffness constants are used to fully define the elastic behaviour of the material [19]. Elastic constants for Tungsten Alloy Samples under analysis were obtained from the velocities of ultrasound that were assessed with ultrasonic pulse echo velocity meter. These results are summarized in Table.1 and Table. 2.

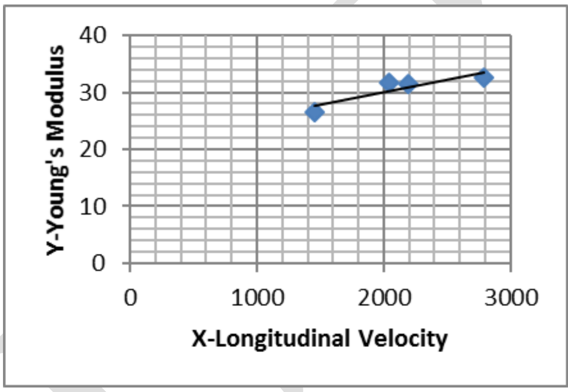
Table.1. Elastic Constants of Tungsten Alloy for Different Holding Time.

YOUNG'S MODULUS GPA	BULK MODULUS GPA	SHEAR MODULUS GPA	POISSON'S RATIO
31.8	39.2	11.7	0.36
32.6	87.0	11.3	0.43
26.6	12.4	11.7	0.14
31.5	47.9	11.3	0.39

Table.2. Elastic constants of tungsten alloy for different temperature.

YOUNG'S MODULUS GPA	BULK MODULUS GPA	SHEAR MODULUS GPA	POISSON'S RATIO
31.8	39.2	11.7	0.36
31.5	48.2	11.3	0.39
32.0	32.1	12.0	0.33
29.7	13.0	11.2	0.32

Further the relationship between ultrasonic wave velocity and elastic constants was studied for the tungsten alloy specimens.



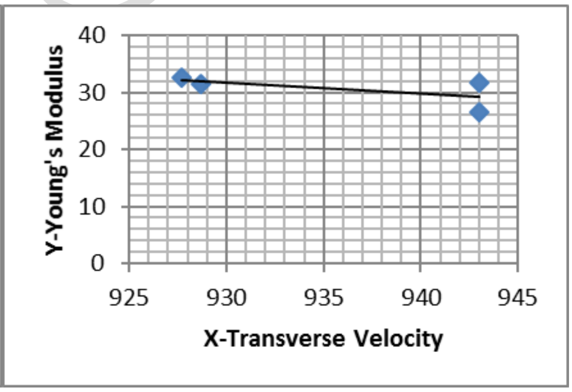


Fig.4.Correlation between Longitudinal velocity and Young's Modulus, correlation between Transverse velocity and Young's Modulus for the heat treated samples at 1500^{0}C for different holding time.

The correlation between ultrasonic velocities and Young's modulus of the tungsten alloy heat treated at 1500 degree Celsius are shown in Fig.4. The correlation between ultrasonic velocities and Bulk modulus of the tungsten alloy heat treated at 1500 degree Celsius are shown in Fig.5.

DOI: 10.15680/IJIRSET.2014.0312016

IJIRSET

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

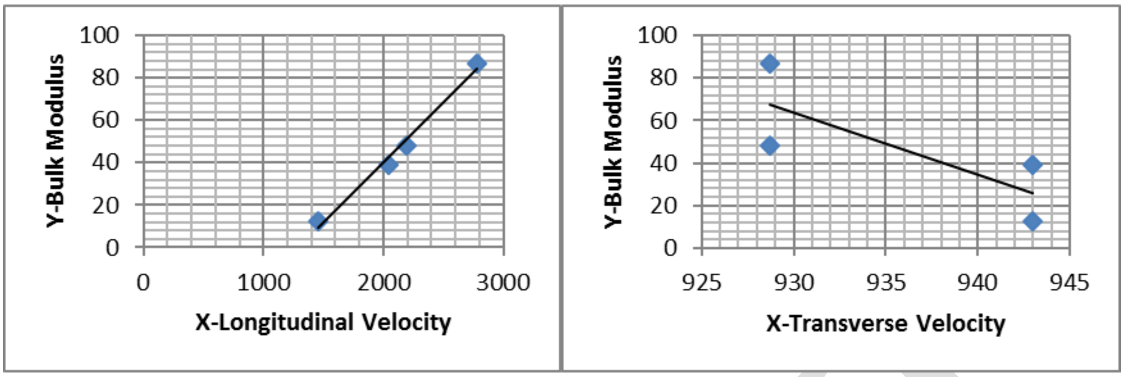


Fig.5. Correlation between Longitudinal velocity and Bulk Modulus, correlation between Transverse velocity and Bulk Modulus for the heat treated samples at 1500^{0}C for different holding time.

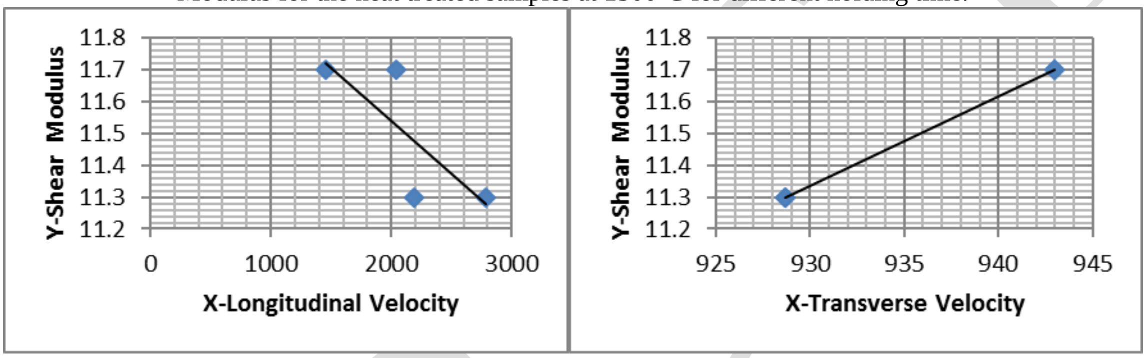


Fig.6. Correlation between Longitudinal velocity and Shear Modulus, correlation between Transverse velocity and Shear Modulus (1500 deg C)

The correlation between ultrasonic velocities and Shear modulus of the tungsten alloy heat treated at 1500 degree Celsius are shown in Fig.6. The correlation between ultrasonic velocities and Poisson's ratio of the tungsten alloy heat treated at 1500 degree Celsius are shown in Fig.7.

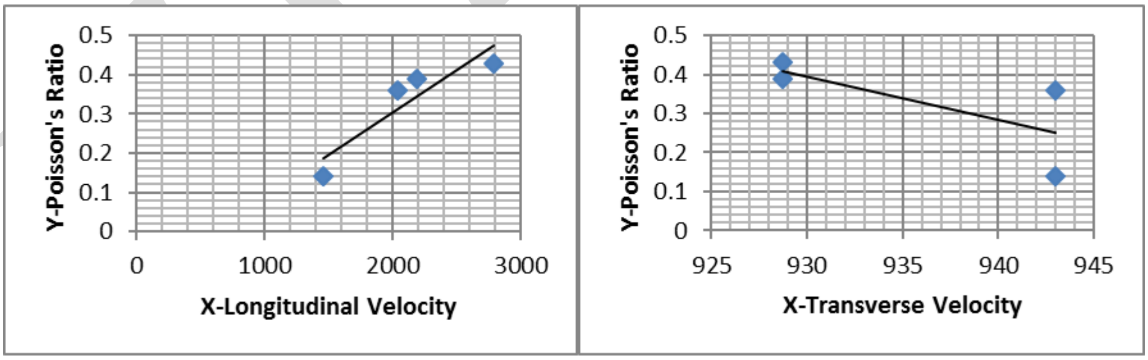


Fig.7. Correlation between Longitudinal velocity and Poisson's Ratio, correlation between Transverse velocity and Poisson's Ratio(1500 deg C)

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Fig. 8 shows the correlation between ultrasonic velocities and Young's modulus of the heat treated tungsten alloy at different temperature ranges. The correlation between ultrasonic velocities and bulk modulus of the heat treated tungsten alloy at different temperature ranges are shown in Fig.9.

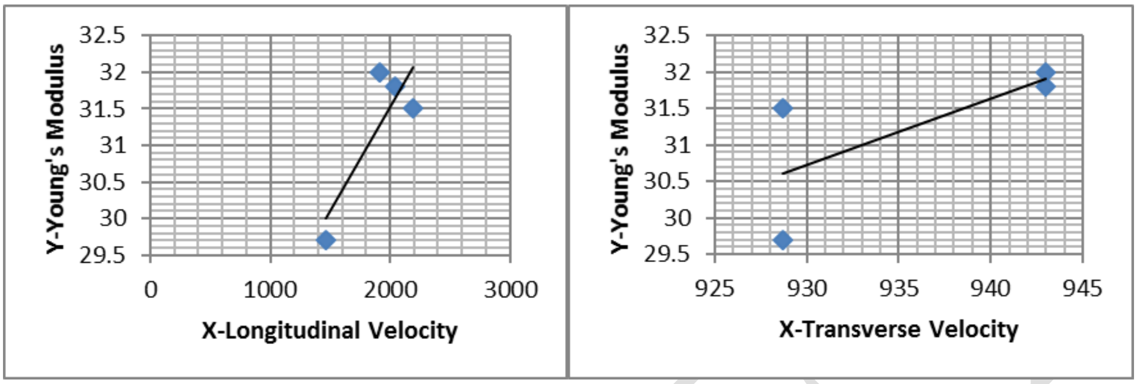


Fig.8. Correlation between Longitudinal velocity and Young's Modulus, correlation between Transverse velocity and Young's Modulus for the samples heated at different temperature.

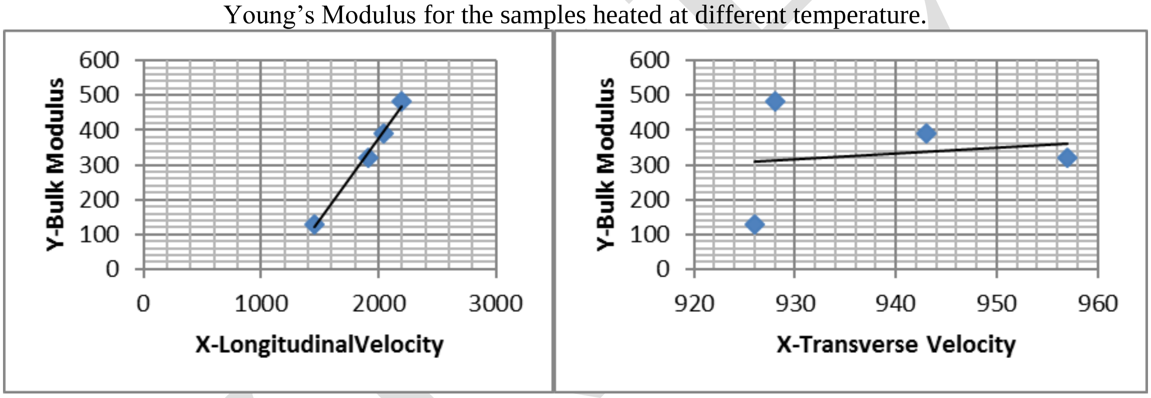


Fig.9. Correlation between Longitudinal velocity and Bulk Modulus, correlation between Transverse velocity and Bulk Modulus for the samples heated at different temperature.

Fig. 10 shows the correlation between ultrasonic velocities and Shear modulus of the heat treated tungsten alloy at different temperature ranges. The correlation between ultrasonic velocities and Poisson's ratio of the heat treated tungsten alloy at different temperature ranges are shown in Fig.11.

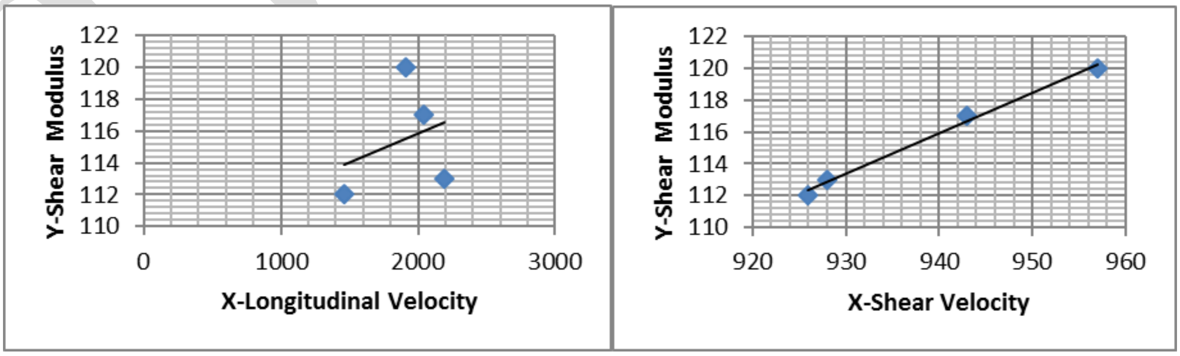


Fig.10. Correlation between Longitudinal velocity and Shear Modulus, correlation between Transverse velocity and Shear Modulus

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

for the samples heated at different temperature.

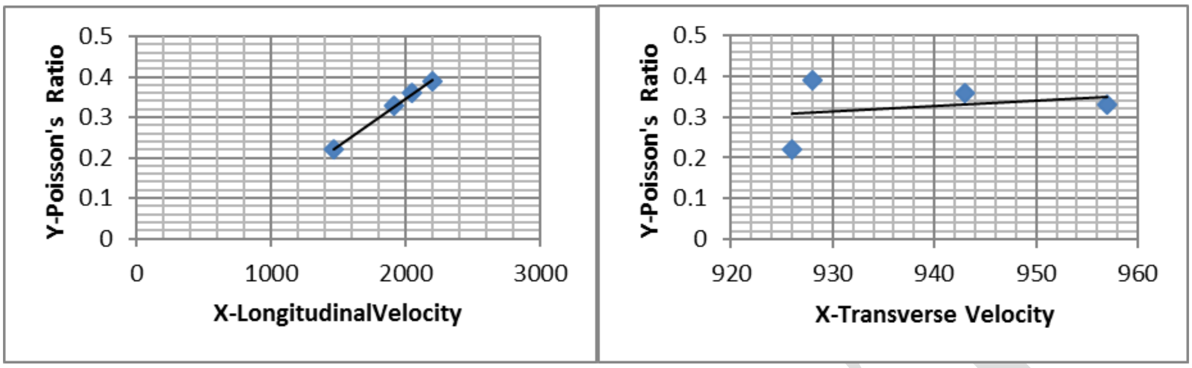


Fig.11. Correlation between Longitudinal velocity and Poisson's Ratio, correlation between Transverse velocity and Poisson's Ratio for the samples heated at different temperature.

IV. CONCLUSION

Tungsten alloys used for TIG welding process is subject to temperature variations. The mechanical characteristics study was conducted on a sample tungsten alloy using ultrasonic technique. The correlation studies on ultrasonic longitudinal and transverse wave velocity with elastic constant indicate that ultrasonic longitudinal wave can be very well used for material characterization, as longitudinal wave velocity has better correlation as compared to transverse wave velocity. The longitudinal velocity shows better correlation than transverse wave velocity. The variation in correlation is due to the change in microstructure of the alloy at different heat treatments.

REFERENCES

[1] American Welding Society, "Welding handbook, welding processes Part 1", American Welding Society, ISBN 0-87171-729-8, 2004.

[2] N.Jeyaprakash, R. Prabhakaran, G. Murugesan,"Weldability Analysis of T23 Material for Superheater Coil", IOSR Journal of Mechanical and Civil Engineering , vol. 11, Issue 6 Ver. I, pp. 01-04, 2014.

[3] Lloyd Ivan Lasdon, Scarsdale, N.Y., "Process for making tungsten and molybdenum alloys", US patent no.3,418,103.

[4] P. Majumdar, S.B. Singh, M. Chakraborty, "The role of heat treatment on microstructure and mechanical properties of Ti–13Zr–13Nb alloy for biomedical load bearing applications", Journal of Mechanical Behavior of Bio-medical Materials, vol. 4, pp. 1132-1144, 2011.

[5] Z.Y. Zhu, et al., "Effect of post weld heat treatment on the microstructure and corrosion behavior of AA2219 aluminum alloy joints welded by variable polarity tungsten inert gas welding", Materials and Design, vol.65, pp. 1075–1082.

[6] Anna Castellano, et al., "Mechanical characterization of CFRP composites by ultrasonic immersion tests: Experimental and numerical approaches", Composites: Part B, vol. 66, pp. 299–310, 2014.

[7] Magdy M. El Rayes, Ehab A. El-Danaf, Abdulhakim A. Alm, " Ultrasonic characterization of heat-treatment effects on SAE-1040and -4340 steels", Journal of Materials Processing Technology, vol. 216, pp. 188–198.

[8] Achenbach JD, "Quantitative non-destructive evaluation", International Journal of Solids and Structures, vol. 37, pp.13–27, 2000.

[9] Robert Weser, et al., "Ultrasonic backscattering method for in-situ characterisation of concentrated dispersions", Powder Technology, vol.268, pp.177–190, 2014.

[10] D.E. Chimenti, "Review of air-coupled ultrasonic materials characterization", Ultrasonics, vol.54, pp.1804–1816, 2014.

[11] K. Vijayalakshmi, V. Muthupandi, R. Jayachitra, "Influence of heat treatment on the microstructure, ultrasonic attenuation and hardness of SAF 2205 duplex stainless steel", Materials Science and Engineering A, vol. 529, pp.447– 451, 2011.

[12] Hakan Gur C., Orkan Tuncer B., "Characterization of micro structural phases of steels by sound velocity measurement", Materials Characterization, vol.55, pp.160– 166, 2005.

[13] P.Palanichamy, M.Vasudevan , T.Jayakumar, S.Venugopal, B.Raj " Ultrasonic velocity measurement for characterizing the annealing behavior of cold worked Austentic stainless steel"NDT&E Inter 33,pp253-259, 2000.

[14] P.Shankar, P.Palanichamy, T.Jeyakumar, Baldev Raj and S.Ranganathan,"Nitrogen Redistribution, Microstructure ad Elastic constant Evaluation using ultrasonics in aged 316 LN Stainless steel"Metal and Matter. Trans A32,pp.959-2968, 2001.

[15] M.A Rodriguez-sastre, L.Calleja, "The determination of elastic modulus of slates from ultrasonic velocity measurement" The geological society of London, paper no 775, 2006.

[16] C. Hakan Gur, B.Orkun Tuncer," Characterisation of microstructural phases of steel by sound velocity measurement", Mater. Char55,pp 160-166, 2005.

[17] P. Palanichamy, A.Joseph, T.Jeyakumar,B.Raj "Ultrasonic velocity measurement for estimation of grainsize in austentic stainless steel"NDT&E Int 28, pp179-85, 1995.

[18] Phani surya kiran mylavarapu, "Characterisation of advanced composites - A nondestructive approach", M.S University of Missouri Kansas city, Ph.D. Thesis, 2007.

[19] Anish kumar ,T.Jeyakumar, baldev raj, K.K.Ray, "Correlation between ultrasonic shear wave velocity and Poisson's ratio for isotropic solid materials" Acta Mater, 51, pp 2417-2426, 2003.