Ultrasonic Non Destructive Technique an effective tool for Characterization of Aluminium

A.R.Golhar
Assistant Professor in Physics
Priyadarshini Bhagwati College of Engineering, Nagpur
India
artigolhar@gmail.com

N.K.Choudhari
Principal
Priyadarshini Bhagwati College of Engineering, Nagpur
India
drnitinchoudhari@gmail.com

Abstract— **Ultrasonic techniques are providing fast and non-destructive information for quality assurance of the composite and help to optimize process parameters. The Ultrasonic parameters are used to indicate the correlation between the acoustic properties and the microstructure of the material. To characterize the aluminium metals by knowing the aluminum and iron percentage present in the Aluminum metals so that it can be classified into the types of aluminium metals which are available. Grade of the aluminium samples help user in a position to decide its applications. In this paper an attempt is made to characterize the aluminium metals by ultrasonic non destructive techniques and signal processing technique. To develop the relationship between aluminum and iron percentage present in the aluminum metals and the various observed NDT parameters such as density, ultrasonic velocity, attenuation, compositions present in aluminium samples, peak amplitude of FFT, Time signal, Power Spectral Density etc IDASM Neural network is used. This Neural model calculates the percentage of aluminium and iron present in the aluminium samples and it is compare with the Experimental data. The impact of various variables on aluminum and iron percentage present in the aluminum samples is also discussed in this paper.**

Keywords— **Ultrasonic, Aluminium, , Characteristics, Neural Network.**

I. INTRODUCTION

Non-destructive testing techniques are most commonly employed for detection and characterization of flaws in the component. Apart from flaw characteristics, another parameter which is equally important to assess the structural integrity of engineering components is the material property. With the development in electronics and digital technology, ultrasonic testing parameters, which are affected by changes in material properties [1,2,3] can be measured with greater accuracy . The ultrasonic wave/microstructure interaction established new methodologies for non-destructive assessment of various microstructures in 9% Chromium ferrites steels useful for practical situations [4]. From non linear ultrasonic assessment the damage parameter can be obtained to quantify pitting damage in 7075 Aluminium alloy [5] and by thermography NDT technique [6]. By heat treatment and age hardening treatments material characterization is done by ultrasonic non destructive techniques. [7,8] The effective elastic constants of the metals composites are calculated by using the values of velocities and the mass densities of composites [9,10].With the development of new technology and use of light weight material such as composite laminates, new methods is develop for in situ structure, health monitoring of these materials[11]. Ultrasonic measurements are useful for determining several important material properties [12]. In this present paper by using ultrasonic non destructive techniques and IDASM Neural Network a relationship is developed between aluminum and iron percentage present in the aluminium sample and various observed NDT parameters.

II. MATERIAL CHARACTERISTICS OBSERVATIONS

The Various specimen used in the experiments has been prepared from aluminium alloys of different grades with different dimensions. For Ultrasonic testing the sample surfaces are smooth to perform investigations. The hardness of alloys has measured by Hardness tester. Digital vernier caliper have been used to measure the thickness and dimensions of the different samples with a greater accuracy. Density of different samples has been calculated using conventional method by knowing the masses of the sample which has measured in digital weighing machine. The chemical composition of aluminium alloys have been observed by OXFORD instrument, which produces x-rays when energized.

Ultrasonic NDT Techniques:

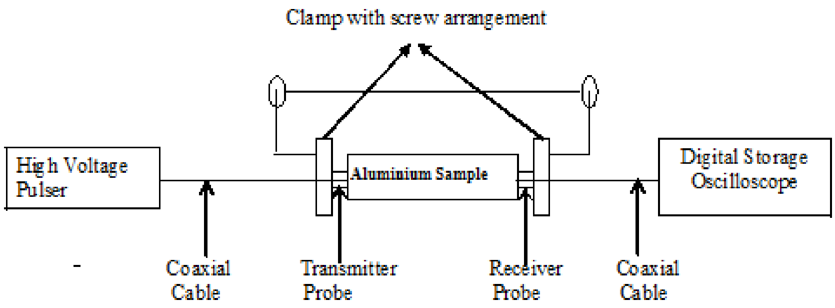
A. Ultrasonic Velocity Measurement

Ultrasonic device Ultrasonic thickness gauge using 5 MHz transducer has been used for the measurement to be carried out. A direct pulse echo method is used for the measurements. The ultrasonic device measures the velocity of the acoustic waves in the aluminium samples. By knowing the thickness or distance between the two parallel external surfaces of the samples in which acoustic wave travel with different composition, Velocity is calculated in m/sec according to the equation

$$\text{Velocity} = \text{Thickness}/ \text{Velocity}$$

B. Ultrasonic attenuation Measurement

The lab set up used for the NDT ultrasonic test is shown in fig (1). The Aluminium samples are placed between the transducer, through BNC cable. The transducer is mounted on the two ends of a clamp as shown in the figure (1). Glycerin is used as a couplant of ultrasonic vibration through transducer



and Aluminium surfaces. The DPR 300 Pulser /receiver of JSR Ultrasonic (USA) have been used to generate high voltage pulse. Ultrasonic transducer is connected to the pulser via cable which converts electrical energy to ultrasonic pulse that is propagated into a test sample. The receiving transducer is used to detect acoustic pulses that have propagated through test sample. The receiving transducer is connected to the TDS2024 200 MHz Testronix Digital Storage Oscilloscope. A pair of MODSONIC transducer of 4MHz has been used as a transmitting and receiving transducer. Attenuation coefficient α, is calculated in dB/mm accordance to equation

$$\alpha = (20/w) \log(Vi/Vo) \quad \text{-----------------} \quad (1)$$

where,

Vi is the input Voltage

Vo is the output Voltage

W is the thickness of the sample

Fast Fourier Transform (FFT) and power Spectral Density (PSD) using MATLAB is used to analyzed the received time signal . The observed values of peak amplitude Time signal, FFT, and PSD have recorded. The Modulus of Elasticity is calculated by following mathematical relation

Modulus of Elasticity MOE = $(\text{velocity})^2$ x (density) in N/m^2

III. RESULTS & DISCUSSIONS

To establish the relation between these observed NDT parameters to characterize the Aluminium metals by calculating the percentage of aluminum & Iron of the sample, the graphs have been plotted for the measurement of percentage of aluminum & Iron with respect to various observed NDT parameters like density, ultrasonic velocity, attenuation, MOE, Peak amplitude of Time signal, FFT, PSD etc.

Percentage of percentage of aluminum & Iron present in aluminium sample by nondestructive ultrasonic method has been investigated with a variety of parameters. Most of this work has been carried out using ultrasonic waveform parameters such as velocity measurement, attenuation, etc. The basis of these studies is that as the percentage of aluminum & Iron present in aluminium samples change and hence changes in ultrasonic signal propagation is observed. However all the said parameters may not be sufficient to characterize the samples and to predict the parentage of aluminum & Iron present in it. There may be different percentage of aluminum & Iron present in samples. It may not affect velocity, but may impact other ultrasonic parameters like attenuation etc.Results obtained using attenuation, density, MOE, densities were not sufficient and hence we introduced frequency domain analysis that has produced very encouraging results. The variation of magnitude of the spectrum can be used as a tool for predicting the percentage of aluminum & Iron.

To calculate the estimated values of percentage of aluminum & Iron in aluminium or the observed NDT parameters Integrated Data Analysis and Stimulation Model (IDASM) Neural Networks model has used. There are large numbers of variables for predicting the percentage of aluminum & Iron of the aluminium Metals which is the dependent variable. The dependency analysis is a technique which allows us to build a mathematical description of the relationship between the independent and dependent variable. The network report is generated by IDASM. It shows the results of trained file . The result is displayed after the file has been trained to the expected levels and accuracy, and the number of iterative cycle is reached. The report contains the impact of independent variables NDT observed parameters on the dependent variables Percentage of aluminium in the sample. Table (1) shows the impact on Aluminium percentage at minimum and maximum values of the Aluminium percentage (dependent variable) by changing the requisite observed NDT parameters (Independent variable) values by 1%. Table (1) shows the summary results of behavior of various NDT observed parameters around minimum and maximum Aluminium percentage.

Table I

Summary Report
Behavior around Minimum AL
AL = (0.01)HARDNESS + (0.01)DENSITY + (-0.01)VELOCITY + (0.00) ATTEN + (0.00)MOE + (0.01)TS Y + (0.01)FFT Y + (0.00)FFT X + (0.00) PSD Y + (0.01)PSD X
Behavior around Maximum AL
AL = (0.00)HARDNESS + (0.01)DENSITY + (0.00)VELOCITY + (0.00) ATTEN + (0.00)MOE + (0.01)TS Y + (0.01)FFT Y + (0.01)FFT X + (0.00) PSD Y + (0.01)PSD X

Table (1) Summary of Network report generated

Table (2) gives the average effect of Independent measured NDT parameters on Aluminium percentage.

Table II

Average effect of independent attributes:-		
Independent Variables	Average Effect on AL	Rank
DENSITY	0.010000	1
TS Y	0.010000	1
FFT Y	0.010000	1
PSD X	0.010000	1
HARDNESS	0.005000	2
FFT X	0.005000	2
ATTEN	0.000000	3
MOE	0.000000	3
PSD Y	0.000000	3
VELOCITY	-0.005000	4

Table (2) Average effect of Independent variables on Aluminium percentage.

Actual and Estimated values for the Aluminium percentage used to build the Neural Networking Model. The graph was plotted between Actual Aluminium percentage measured experimentally and the estimated Aluminium percentage by ISDAM Neural network model as shown in fig (3). The value of coefficient of determination R^2 is close to 1, it shows the extremely good fit of data. The ISDAM Neural network model build for this study shows more than 99% accuracy and error is less than 1%.

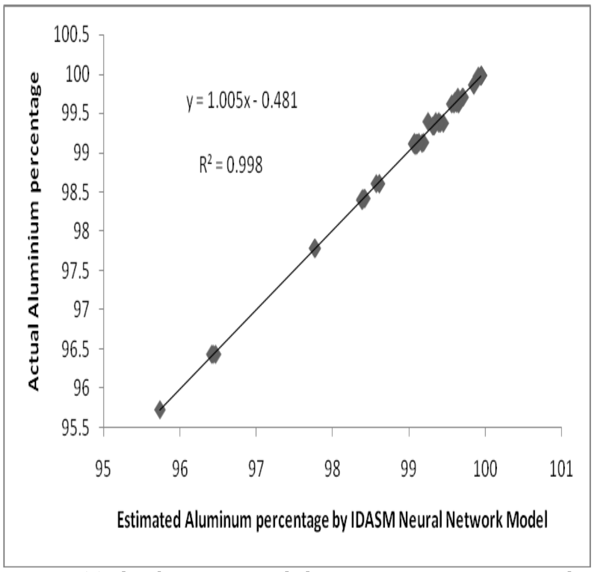


Figure (3) plots between Actual aluminium percentage measured experimentally by Estimated aluminium percentage by ISDAM Neural Network Model of all samples of aluminium.

Similarly the report contains the impact of independent variables NDT observed parameters on the dependent variables iron percentage in the sample are also obtained. Table (3) shows the impact on iron percentage at minimum and maximum values of the iron percentage (dependent variable) by changing the requisite observed NDT parameters (Independent variable) values by 1%. Table (3) shows the summary results of behavior of various NDT observed parameters around minimum and maximum iron percentage.

Table (4) gives the average effect of Independent measured NDT parameters on iron percentage.

Summary Report
Behavior around Minimum FE
FE = (0.56)HARDNESS + (0.63)DENSITY + (1.83)VELOCITY + (0.23)ATTEN + (-2.48)MOE + (-0.23)TS Y + (-0.06)FFT Y + (1.23)FFT X + (0.16)PSD Y + (0.05)PSD X
Behavior around Maximum FE
FE = (0.03)HARDNESS + (0.09)DENSITY + (0.19)VELOCITY + (0.05)ATTEN + (0.00)MOE + (-0.05)TS Y + (-0.02)FFT Y + (0.25)FFT X + (0.03)PSD Y + (-0.34)PSD X

Table III

Table (3) Summary of Network report generated actual and estimated values for the iron percentage used to build the Neural Networking Model.

Table IV

Average effect of independent attributes:-		
Independent Variables	Average Effect on FE	Rank
VELOCITY	1.010000	1
FFT X	0.740000	2
DENSITY	0.360000	3
HARDNESS	0.295000	4
ATTEN	0.140000	5
PSD Y	0.095000	6
FFT Y	-0.040000	7
TS Y	-0.140000	8
PSD X	-0.145000	9
MOE	-1.240000	10

Table (4) Average effect of Independent variables on iron percentage

The graph was plotted between Actual iron percentage measured experimentally and the estimated iron percentage by IDASM Neural network model as shown in fig (4). The value of coefficient of determination R^2 is close to 1, it shows the extremely good fit of data. The IDASM Neural network model build for this study shows more than 99% accuracy and error is less than 1%.

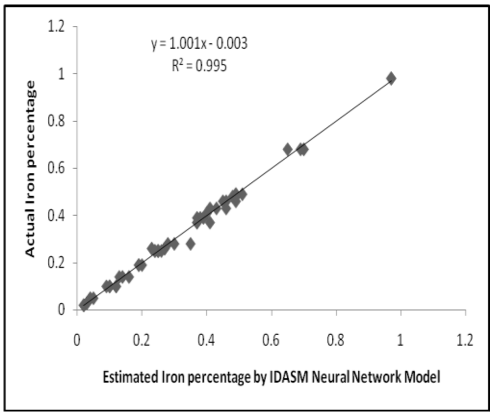


Figure (4) plot between Actual iron percentages measured experimentally by estimated iron percentage by IDASM Neural Network Model of all samples of aluminium

IV. CONCLUSIONS

The result of this study demonstrates Digital signal processing used for ultrasonic signals associated with the IDASM Neural Network having the potential for estimating the percentage of aluminium and iron in aluminium sample which may help to identify the type of aluminium metals, process control, quality assurance and predicting the applications of existing aluminium metal. Due to this user may be in a position to decide the application of aluminium sample. However, it is to be noted that the system needs further validation before it made as commercial product. This will require a large data base to be collected and documentation from various sources.

REFERENCES

[1] P.P. Nanekar and B. K. Shah, **‘**characterization of material properties by ultrasonics’, *BARC Newsletter*, Issue No. 249, pp. 25-38.

[2] Dong Fei, David K. Hsu, and Mark Warchol, ‘Simultaneous Velocity, Thickness and Profile maging by Ultrasonic Scan’ *Journal of Nondestructive Evaluation*, Vol. 20, No. 3, September (2001).

[3] A.R.Golhar,N.K.Coudhari, ‘ Characteristics of alumnium metals by ultrasonic Non-Destructive Techniques using Digital signal processing’ International Journal for Research and development in Technology, Volume 5, Issue 56, May 2016, P.P. No.292-295

[4] Anish Kumar, B.K. Choudhary, K. Laha, T. Jayakumar, K. Bhanu Sankara Rao and Baldev Raj, ‘characterisation of microstructure in 9 % chromium ferritic steels using ultrasonic Measurements’, *Trans. Indian Inst. Met*.Vol.56, No. 5, (October 2003), pp. 483-497.

[5] Santanu De, S. Palit Sagar, S. Dey, Amit Prakash, I. Chattoraj, ‘Quantification of pitting in two tempers of 7075 Aluminium alloy by non-destructive evaluation’, *Corrosion Science*, 52, (2010), pp.1818-1823.

[6] M.P.Luong, ‘Infrared thermographic scanning of Fatigue in *Metals’ Elsevier Science Publishers*, 1993

[7] Fawad Tariq · Nausheen Naz · Rasheed Ahmed Baloch ·Faisal, ‘Characterization of Material Properties of 2xxx Series Al-Alloys by Non Destructive Testing Techniques’,*Journal of Nondestructive Eval, Springer* Science, (2011).

[8] M. Rosen, L.Ives, S.Ridder and F.Biancaniello, R. Mehrabian, ‘Correlation between Ultrasonic and Hardness Measurements in Aged Aluminium Alloy 2024’ , *Materrial Science and Engineering*, 74, (1985),pp. 1-10.

[9] M.O.Si-Chaib,S.Menad.H.Djelouah, M. Bocquet ‘An ultrasound method for the acoustoelastic Evaluation of simple bending stresses’ *NDT&E International* 34 , (2001), 521-529.

[10] Zi-quan Li, Xiao-rong zhang, Shu-Yi Zhang, Zhonga-hua Shen ‘Determination of the elastic constants of metal-matrix composites by a laser ultrasound technique’,*Journal of composite Science and Technology*, 61,(2001), pp1457-1463.

[11] Macro Alfano, Leonardo pagnotta ‘A non-destructive technique for the elastic Characterization of thin isotropic plates’ *NDT&E International*, 40 ,(2007), pp112-120.

[12] Meftaf Hrairi, Mirghani Ahmed, Yassin Nimir ‘Compaction of fly ash-Aluminium alloy composites and evaluation of their mechanical and acoustic properties’ *Advance power Technology* ,20 , (2009) , pp548-553.