A TECHNIQUE TO CHARACTERIZE THE ALUMINIUM BY USING ULTRASONIC NON DESTRUCTIVE TECHNIQUES

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Abstract:Ultrasonic testing is traditionally used for flaw detection and characterization of the Materials. Ultrasonic testing for material characterization not only play a vital role in quality assurance during in-manufacture inspection but also can serve as a powerful tool for life prediction technology during in-service inspection, residual life assessment and plant life extension. Hardness and aluminium percentage is one of the important characteristic of aluminium Metals. Hardness and aluminium percentage of the Aluminium metals which depends on the type or grade and the composition play very important role. If the Hardness and aluminium percentage of the aluminium samples is known then user is in a position to decide their applications. In this paper an attempt is made to characterize the aluminium metals by ultrasonic non destructive techniques and signal processing technique. IDASM Neural network is used to develop the relationship between Hardness and aluminium percentage 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. This Neural model calculates the Hardness and aluminium percentage present in the aluminium samples and it is compare with the Experimental data. The impact of various variables on Hardness and aluminium percentage are also discussed in this paper.

Key words: Ultrasonic, Aluminium, Hardness, Characteristics, Neural Network.

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 advancement in electronics and digital technology, ultrasonic testing parameters, which are affected by changes in material properties [1,2] can be measured with high accuracy to provide a reasonable confidence level. The ultrasonic wave/microstructure interaction established new methodologies for non-destructive assessment of various microstructures in 9% Chromium ferrites steels useful for practical situations [3]. The damage parameter can be obtained from non linear ultrasonic assessment to quantify pitting damage in 7075 Aluminium alloy [4] and by thermography NDT technique [5]. By heat treatment and age hardening treatments material characterization is done by ultrasonic non destructive techniques. [6,7] The effective elastic constants of the metals composites are calculated by using the values of velocities and the mass densities of composites [8,9].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[10]. Ultrasonic measurements are useful for determining several important material properties [11]. In this present paper by using ultrasonic non destructive techniques and IDASM Neural Network a relationship is developed between Hardness and aluminium percentage in the Aluminium sample and various observed NDT parameters.

II.MATERIAL CHARACTERISTCS OBSERVATION

The Various specimen used in this investigation has been prepared from Aluminium alloys of different grades and they have different dimensions. The sample surfaces are smooth to perform ultrasonic testing. The hardness of alloys has measured by Hardness tester. The thickness and dimensions of the different samples have been recorded by using digital vernier caliper with a greater accuracy. Density of different samples has been calculated 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.

III. ULTRASONIC NDT TECHNIQUES:

A.ULTRASONIC VELOCITY MEASUREMENT

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

$$\text{Velocity} = \frac{\text{Thickness}}{\text{Time of Flight}} \qquad \text{---------(1)}$$

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.

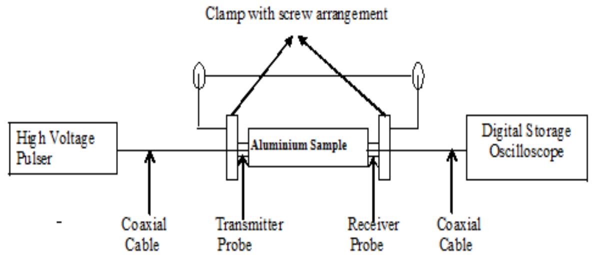

Fig (1) Experimental Set-up

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

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

where,

Vi is the input Voltage

Vo is the output Voltage

W is the thickness of the sample

The received time signal is analyzed by getting the Fast Fourier Transform (FFT) and power Spectral Density (PSD) using MATLAB. 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

IV. RESULTS AND DISCUSSIONS

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

Hardness and aluminium percentage 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 the ultrasonic signal propagation changes with the Hardness and aluminium percentage in Aluminium samples.

However all these parameters may not be sufficient to characterize Aluminium sample and to predict the Hardness of the sample. There may be different Hardness and aluminium percentage present in one sample. It may not affect velocity, but may impact other ultrasonic parameters.
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 Hardness and aluminium percentage.

Integrated Data Analysis and Stimulation Model (IDASM) Neural Networks model has used to calculate the estimated values of Hardness and aluminium percentage in Aluminium, for the observed NDT parameters. There are large numbers of variables for predicting the Hardness and aluminium percentage of 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 Hardness in the sample.

Summary Report
Behavior around Minimum HARDNESS
HARDNESS = (1.24)DENSITY + (5.77)VELOCITY + (-0.22)ATTEN + (-0.25)MOE + (0.10)TS Y + (0.00)FFT Y + (1.22)FFT X+ (-0.31)PSD Y + (0.20)PSD X + (11.56)AL + (-0.02)CR + (-0.02)FE + (0.01)CU + (0.02)MN + (0.00)NI + (0.03)ZN + (0.00)TI + (0.00)PB + (0.00)V
Behavior around Maximum HARDNESS
HARDNESS = (0.16)DENSITY + (-0.01)VELOCITY + (0.00)ATTEN + (-0.20)MOE + (0.06)TS Y + (0.04)FFT Y + (0.30)FFT X+ (-0.02)PSD Y + (0.01)PSD X + (0.43)AL + (0.01)CR + (0.01)FE + (0.01)CU + (0.02)MN + (0.01)NI + (0.06)ZN + (0.00)TI + (0.00)PB + (0.00)V

Table (1) Summary of Network report generated

Table (1) shows the impact on Hardness at minimum and maximum values of the Hardness (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 Hardness.

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

Average effect of independent attributes:-		
Independent Variables	Average Effect on HARDNESS	Rank
AL	5.995000	1

VELOCITY	2.880000	2
FFT X	0.760000	3
DENSITY	0.700000	4
PSD X	0.105000	5
TS Y	0.080000	6
ZN	0.045000	7
FFT Y	0.020000	8
MN	0.020000	8
CU	0.010000	9
NI	0.005000	10
TI	0.000000	11
PB	0.000000	11
V	0.000000	11
CR	-0.005000	12
FE	-0.005000	12
ATTEN	-0.110000	13
PSD Y	-0.165000	14
MOE	-0.225000	15

Table (2) Average effect of Independent variables on Hardness

Actual and Estimated values for the Hardness used to build the Neural Networking Model. The graph has plotted between Actual Hardness measured experimentally and the estimated Hardness 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%.

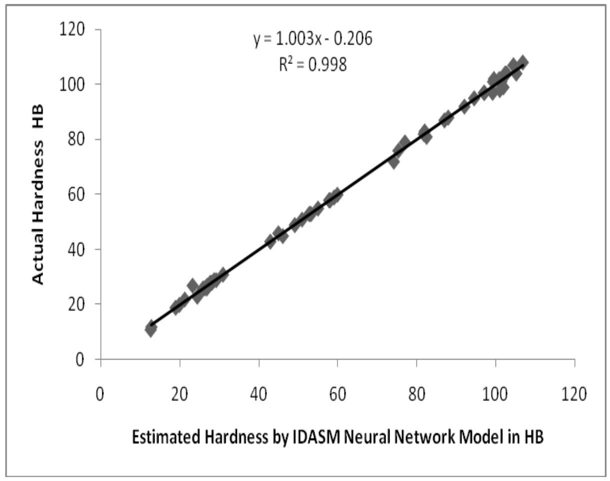

Figure (3) plot between Actual Hardness measured experimentally by Estimated Hardness by ISDAM Neural Network Model of all samples of Aluminium.

Similarly the processes is repeated for aluminium percentage in aluminium sample.

<u>Summary Report</u>
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 (3) Summary of Network report generated

Table (3) 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 (3) shows the summary results of behavior of various NDT observed parameters around minimum and maximum Aluminium percentage. Table (4) gives the average effect of Independent measured NDT parameters on Aluminium percentage.

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
PSD Y	0.000000	3
VELOCITY	-0.005000	4

Table (4) 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 IDSAM 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 ISDAM Neural network model build for this study shows more than 99% accuracy and error is less than 1%.

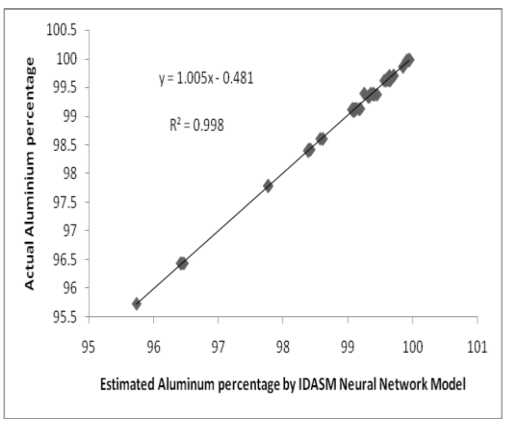

Figure (4) plots between Actual Aluminium percentage measured experimentally by Estimated Aluminium percentage by ISDAM Neural Network Model of all samples of Aluminium.

V. CONCLUSIONS

The result of this study demonstrates the potential for estimating the Hardness and percentage of aluminium of Aluminium sample which may help to identify the type of Aluminium metals, process control, quality assurance and predicting the applications of existing Aluminium metal. However, it is to be noted that the system needs further validation before it made as commercial product. This will require a large data

FFT X	0.005000	2
ATTEN	0.000000	3
MOE	0.000000	3

base to be collected and documentation from various sources.

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