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Simulation Technique Used to Evaluate the Characteristic of Aluminium Metals by Ultrasonic Non-Destructive Techniques

KEYWORDS: Aluminium, characteristics, ultrasonic, neural network

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ABSTRACT *Variety of applications of aluminium metals lead to a significant interest in sorting or grading using non-destructive evaluation techniques. The types of aluminium metals for various engineering is related to the intrinsic percentage of aluminium itself and other elements like iron, manganese etc. If the type of aluminium metals can be determine at early stage of processing then it can be directed to the best possible use. If additional to grade if the hardness of the aluminium metal is known accordingly it can be utilized for various 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 aluminium percentage and hardness with the various observed NDT parameters. This model calculates the aluminium percentage and hardness present in the samples and compares with the experimental data and discussed.*

INTRODUCTION

Ultrasonic testing is traditionally used for flaw detection and characterization. The spectrum of ultrasonic testing applications is widened by its use for material characterization. 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 aluminium percentage and hardness in the aluminium sample and various observed NDT parameters.

MATERIAL CHARACTERISTICS 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.

ULTRASONIC NDT TECHNIQUES

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

Velocity=Thickness/Time (m/sec) (1)

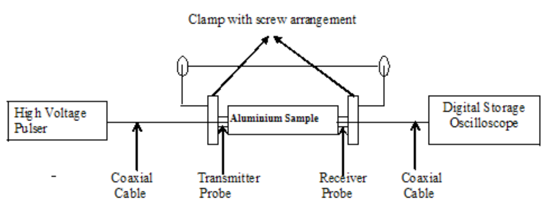

Figure 1: Experimental set up

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

α = (20/w) log (Vi/Vo) (dB/mm) (2)

where,

Vi is the input Voltage

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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 = $(\text{velocity})^2 \times (\text{density})$

(N/m^2) (3)

RESULTS AND DISCUSSIONS

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

Aluminium percentage and hardness in aluminium sample by nondestructive ultrasonic method have 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 aluminium percentage and hardness in aluminium samples.

However all these parameters may not be sufficient to characterize aluminium sample and to predict the aluminium percentage and hardness of the sample.

There may be different types of aluminium percentage and hardness present in one sample. It may not affect density, 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 aluminium percentage and hardness.

Integrated Data Analysis and Simulation Model (IDASM) neural networks model has used to calculate the estimated values of percentage of aluminium and hardness, for the observed NDT parameters. There are large numbers of variables for predicting the percentage of aluminium and hardness of aluminium metals which are 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 and hardness in the sample.

The network report has been generated by IDASM. The report contains the impact of independent NDT parameters on the dependent variables percentage composition of aluminium and hardness. The impact on minimum and maximum values of the aluminium percentage and hardness (dependent variable) by changing the requisite observed NDT parameters (Independent variable) values by 1% is calculated by IDASM . Table (1) shows the summary results of behavior of various NDT observed parameters around minimum and maximum aluminium percentage. Table (2) shows the summary results of behavior of various NDT observed parameters around minimum and maximum hardness. Table (3) gives the average effect of Independent measured NDT parameters on aluminium percentage and Table (4) gives the average effect of Independent measured NDT parameters on hardness of samples.

TABLE – 1
THE SUMMARY RESULTS OF BEHAVIOR AROUND MINIMUM AND MAXIMUM ALUMINIUM PERCENTAGE

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 – 2
THE SUMMARY RESULTS OF BEHAVIOR AROUND MINIMUM AND MAXIMUM HARDNES

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 + (-0.0)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 – 3
AVERAGE EFFECT OF INDEPENDENT VARIABLES 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
FFT X	0.005000	2
ATTEN	0.000000	3
MOE	0.000000	3
PSD Y	0.000000	3
VELOCITY	-0.005000	4

TABLE – 4
AVERAGE EFFECT OF INDEPENDENT VARIABLES 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

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Actual and estimated values for the aluminium percentage and hardness used to build the Neural Networking Model. The graph was plotted between actual aluminium percentage measured experimentally and the estimated aluminium percentage by IDASM Neural network model as shown in fig (2) and the graph was plotted between actual hardness measured experimentally and the estimated hardness by IDASM 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 IDASM Neural network model build for this study shows more than 99% accuracy and error is less than 1%.

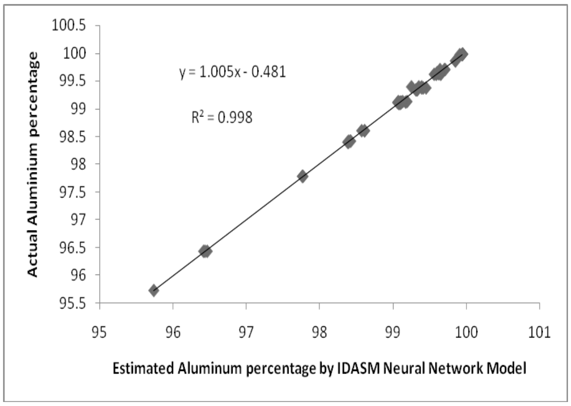

Figure 2: Plots between actual aluminium percentages measured experimentally by estimated aluminium percentage by IDASM Neural Network Model

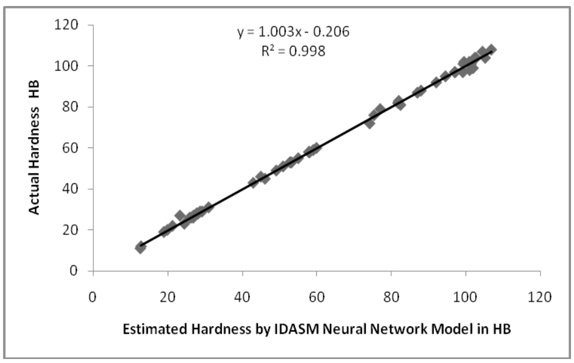

Figure3: plots between actual hardness measured experimentally versus estimated hardness by IDASM neural network model.

CONCLUSIONS

The result of this study demonstrates the potential for estimating the aluminium percentage and hardness 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. In this research the ultrasonic nondestructive technique has been used to predict the percentage of aluminium and hardness of the aluminium metals. FFT, PSD give more information about the signal frequency and energy of the signal that is moving inside the samples which also contribute for the calculation of said parameters in aluminium samples. The IDASM neural network module helped to judge the estimated percentage of aluminium and hardness of the aluminium metals with maximum accuracy.

This research work provides and helps to make the NDT monitoring system for the analysis of characterization of aluminium metals.

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