Investigation of Iron composition in Aluminium by Ultrasonic Non Destructive technique using Digital signal processing

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Abstract - *The addition of alloying elements to aluminum is the principal method used to produce a selection of different materials that can be used in a wide assortment of structural applications. Iron is the most common impurity found in aluminum. It has a high solubility in molten aluminum and is therefore easily dissolved at all molten stages of production. Aluminium metals are classified into different grads or type according to the Aluminium percentage and other elements present in the Aluminium metals. Signal processing involves techniques that improve our understanding of information contained in the received ultrasonic data. In this paper digital signal processing is used to determine the iron percentage in Alumnium sample. IDASM Neural network is used to develop the relationship between iron percentage and the various observed NDT parameters such as hardness, density, ultrasonic velocity, attenuation, peak amplitude of FFT, Time signal, Power Spectral Density etc. This model calculates the iron percentage present in the Aluminium samples and then we can compare with the Experimental data. The impact of various variables on Iron percentage is also discussed in this paper.*

Keywords: Alumnium, Digital signal Processing, Characterization, Ultrasonic

1.INTRODUCTION *(Size 11 , cambria font)*

DSP is the primary means of detecting, conditioning and automatically classifying a variety of signal types. Unfortunately ultrasonic Nondestructive Evaluation (UNDE) development has not exploited the advantages offered by DSP implementation. Compared to analog signal processing systems digital systems have the various advantages.[1]The ultrasonic testing parameters useful for material characterization studies and also explained the investigations carried out in various laboratories on characterization of microstructural and mechanical properties of materials, qualification of processing treatments during fabrication and assessment of damage during service due to various degradation mechanisms [2].The application of the signal processing methods allows the detection of interfaces and hence the location of faults.Ultrasound method for the evaluation of acoustoelasticity in stressed and elastically deformed media when they are submitted to bending stresses [3].The DSP method associated with the neural network for the multilayered media was discussed by J.M.Rouvaen, K. Harrouche, M. Quark and B.El.Khaldi [4]. The DSP method used for acoustic and ultrasonic signals is used for the material testing. The neural Network signal processing technique had been used for analyzing ultrasonic signals [5]. The neural network approach was used for NDT of multilayered structures [6-9].

In this present paper by using Digital signal processing used for ultrasonic signals associated with the IDASM Neural Network a relationship is developed between Iron percentage in the Aluminium sample and various observed NDT parameters.

1.1 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. The chemical composition of Aluminium alloys have been observed by OXFORD instrument, which produces x-rays when energized.

1.2 Ultrasonic NDT Techniques:

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

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

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.

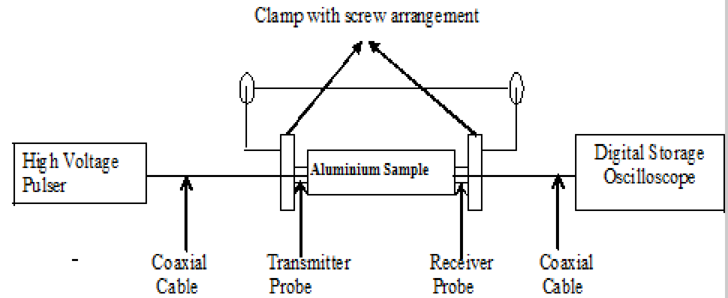

Fig (1) Experimental Set-up

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

$\alpha = (20/w) \log(V_i/V_o)$ ----------------- (1)

where,

V_i is the input Voltage

V_o is the output Voltage

W is the thickness of the sample

The received time signal is analyzed by getting the Digital Signal Processing using Fast Fourier Transform (FFT) and power Spectral Density (PSD) using MATLAB. The observed values of peak amplitude Time signal, FFT, and PSD have recorded as shown in fig 2. The Modulus of Elasticity is calculated by following mathematical relation

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

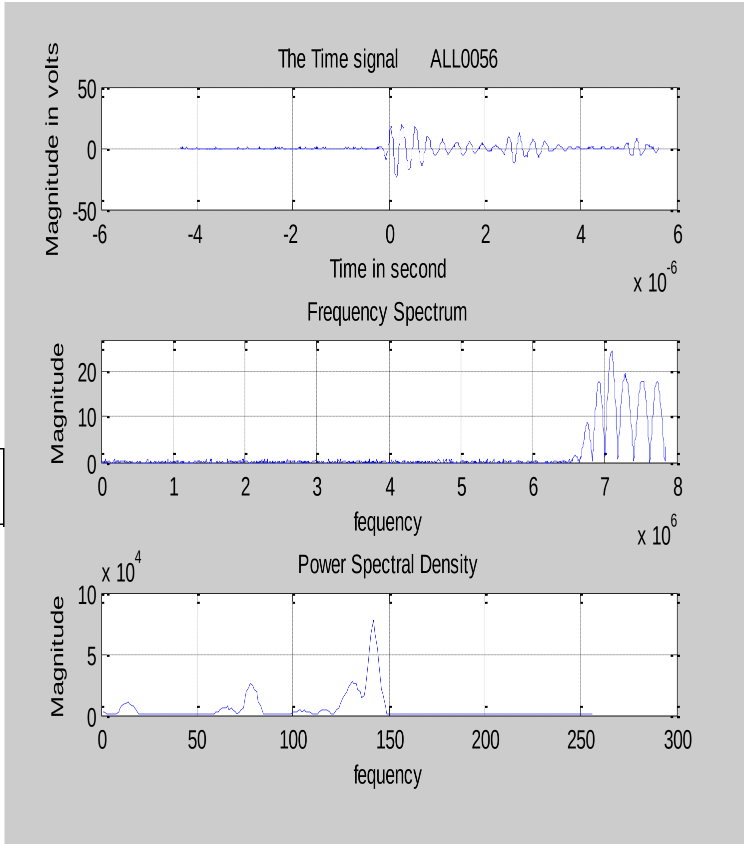

Figure (2) Received ultrasonic signal through Aluminium Sample

2.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 iron percentage with respect to various observed NDT parameters like density, ultrasonic velocity, attenuation, MOE, Peak amplitude of Time signal, FFT, PSD etc.

Iron 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 iron percentage in Aluminium samples. However all these parameters may not be sufficient to characterize Aluminium sample and to predict the iron percentage of the sample. There may be different iron percentage present in different samples. 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 Digital signal processing using 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 iron percentage.

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

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 (1) Summary of Network report generated

Table (1) 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 (1) shows the summary results of behavior of various NDT observed parameters around minimum and maximum iron percentage. Table (2) gives the average effect of Independent measured NDT parameters on iron percentage.

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

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 (2) Average effect of Independent variables on iron percentage

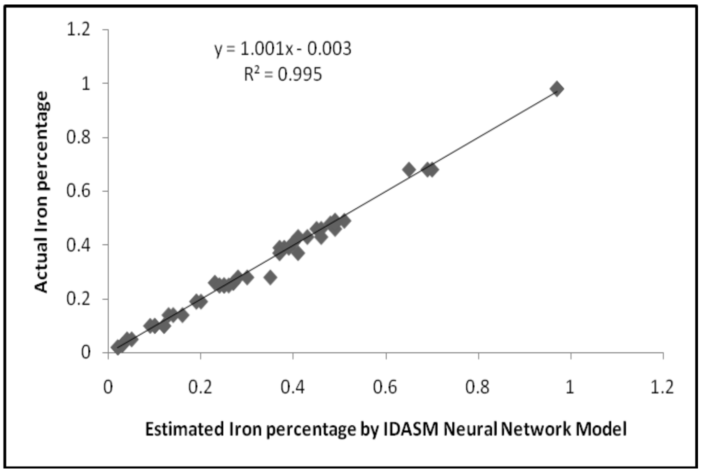

Figure (3) plot between Actual iron percentage measured experimentally by Estimated iron percentage by IDASM Neural Network Model of all samples of Aluminium.

3. 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 iron percentage 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 base to be collected and documentation from various sources.

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