Measurement of velocity and attenuation of Coal by using Ultrasonic NDT

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***Abstract* - Coal is used for power generation, steel making, cement production and many other industrial purposes. Every year, billions of tones of coal is traded in National and international markets Coal is highly heterogeneous in nature consisting of particles of various shapes and sizes having different composition. Conventional coal test methods are well established and are widely used in laboratories worldwide. However, these methods often involve the use of wet analysis or the use of typical laboratory bench-scale apparatus and can be time consuming.. The rapid increase in coal utilization in the twenty-first century led to the development of a number of test methods for coal analysis so as to correlate coal composition and properties with its performance and behavior .Over the years, new methods are continually being developed and the accepted methods are modified/ optimized to increase the accuracy of the technique as well as the precision of the results. Ultrasonic testing is traditionally used for flaw detection and characterization of the Materials. The use of ultrasonic techniques for the characterization of material has attracted much attention in recent years. Although the measurement of ultrasonic parameters has been used for determining material properties for many years, but with the advent of modern signal processing techniques it is possible to extract significant information from ultrasonic signals.In this paper an attempt is made to measure velocity and attenuation of Coal sample using ultrasonic Non-destructive technique, by transmitting ultrasonic wave having frequency 54KHz through ultrasonic transmitter at one surface of coal sample and received at other end using ultrasonic receiver.**

***Key words* - Ultrasonic, Coal, NDT, Velocity, attenuation.**

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 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.

Coal is an extremely complex, heterogeneous material that exhibits a wide range of physical and chemical properties. The rapid increase in coal utilization in the twenty-first century led to the development of a number of test methods for coal analysis so as to correlate coal composition and properties with its performance and behavior during applications such as coal combustion and gasification. Over the years, new methods are continually being developed and accepted methods are modified/optimized to increase the accuracy of the technique as well as the precision of the results. However, by careful analyses of coal that the various aspects of coal usage can be achieved in an effective and environmentally acceptable manner. In this paper we have explained, one of the NDT method to calculate Velocity and Attenuation of coal sample which is probably first time used by any researcher, The pulse velocity in a material depends on its density and its elastic properties, which in turn are related to the quality and the compressive strength of the material [3]. The properties of materials depend upon their composition, structure, synthesis and processing. Properties of materials depend strongly on the structure, even if the composition of the material remains same. The ultrasonic velocity and attenuation are the important parameters of the ultrasonic non-destructive technique of material characterization When the ultrasonic wave propagates through the medium, some part of it's energy is attenuated through the different mechanism like thermal loss, scattering, absorption, electron-photon interaction, photon-photon interaction, and magnon-photon interaction etc., called as ultrasonic attenuation.[4]

II. MATERIAL CHARACTERIZATION TECHNIQUES (NDT & DT)

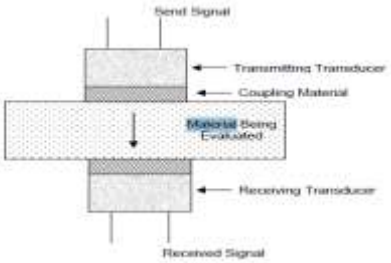
The two major classification of material characterization technique are non-destructive testing (NDT) and destructive testing (DT). Under destructive technique (such as: tensile testing, creep testing, impact testing, torsion testing, hardness testing etc.) of characterization the tested material or product cannot be used again. The destruction of test object usually makes this type of test more costly and tested material is normally of no use. Non-destructive testing technique is a specific procedure whereby the service ability of materials or components is not impaired by testing process. The various methods like visual testing, liquid penetrate testing, magnetic particle testing, eddy current testing, radiographic testing; ultrasonic testing, leak testing, thermographs and neutron radiography are the NDT technique of material characterization.

Among the various non-destructive testing and evaluation (NDT&E),ultrasonic rays plays a key role in material characterization. Ultrasonic properties provide important diagnostic for micro structural properties as well as deformation processes in a material, controlling material behavior based on the physical mechanism. It also help us to predict future performance of the materials.

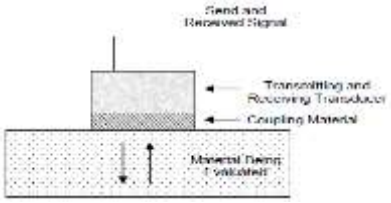
Basic Principles of Ultrasonic Testing

The theory of ultrasonic propagation and that of audible sound are exactly the same. The only difference between them is that ultrasound cannot be detected by the human ear. Ultrasonic testing uses high frequency sound energy above 20 kHz to make measurements. The wave velocity of ultrasonic waves can be determined by two modes of measurements: Through transmission and pulse echo.

In through transmission, two transducers are used; one is the transmitter and the other one is the receiver (Figure 1a). On the other hand, in the pulse echo procedure, only one transducer is used which delivers the pulse and also receives the reflected signal (Figure 1b).



Figure(1a):Through Transmission



Figure(1b):Pulse Echo

Ultrasonic Velocity Measurement

The measurement of ultrasonic velocities depends on propagating a dynamic pressure wave (pulse) through a material of known thickness and measuring the transit time of the emerging acoustic pressure wave. After measuring the transit time of wave, Ultrasonic Pulse Velocity is calculated by dividing the thickness of material to the transit time. The measurement has been carried out using an ultrasonic device " The Proceq Tico ultrasonic instrument " having Voltage pulse of 1kV using 54 kHz Transducers . A direct method is used for the measurements. The ultrasonic device measures the Velocity of the Coal samples by knowing the thickness or distance between the two parallel external surfaces of the samples in which acoustic wave travel. The distance between the transducers is calculated using digital vernier caliper. For automatic display of the pulse velocity in the measurement screen, the distance between the transducers must be input with an accuracy of 1 % using the ↑↓←→ keys.

Input settings in the Menu and then press the "End" key.

- Apply coupling paste to contact surfaces of the transducers and to the points on the object to be measured (thin coat for fine coal surface, thicker coat for rough surface.
- Press "Start" key.
- Position transducers exactly on the measurement points and press down.

During the measuring time, only t is displayed. As soon as the measured value is stable for 3 seconds, a beep is heard and the pulse velocity is displayed under v.

Fig (2) Experimental Set-up for Velocity Measurement

Velocity is calculated in m/sec according to the equation

Velocity= (Thickness/ Transit Time of Wave) ----------(1)

Ultrasonic Attenuation Measurement

A typical ultrasonic testing system consists of a pulser/receiver, transducer, and display devices. High voltage electrical pulse is produced by the pulser/receiver which is an electronic device. The transducer, which can transform the mechanical energy into electrical energy and vice versa, generates high frequency ultrasonic energy. The sound energy propagates through the materials in the form of waves. Through transmission is preferred in coal because of its highly attenuative nature. Attenuation is the reduction in the energy of the wave as it passes through the medium.

The laboratory set up used for the NDT ultrasonic test is shown in fig (2). The Coal samples are placed between the transducer, through BNC cable. The transducer is mounted on the two ends of a sample as shown in the figure (2). Glycerin is used as a couplant of ultrasonic vibration through transducer and Coal surfaces. The DPR 300 Pulser /receiver of JSR Ultrasonic (USA) have been used to generate high voltage pulse.

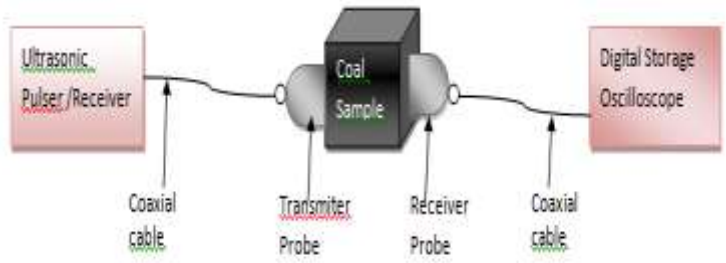


Fig (3) Experimental Set-up for attenuation

Ultrasonic transducer is connected to the pulser via cable which converts electrical energy to ultrasonic wave that is propagated through 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 Digital Storage Oscilloscope. A pair of MODSONIC transducer of 54 KHz has been used as a transmitting and receiving transducer. Attenuation coefficient α, is calculated in dB accordance to equation

$\alpha = (20 \log(Vi/Vo))$ ---------- (2

where,

Vi is the input Voltage

Vo is the output Voltage

OBSERVATION

Table 1 : Observation table of Different Coal Sample.

Name of sample	Length/ Distance (mm)	Time (us)	Velocity (m/s)	Peak To Peak Amplitude (mv)	(Vo/Vi)	Attenuation in (db)
COAL001	37	61.6	600	105	0.51	5.73
COAL002	44	23.7	1860	92.8	0.45	6.80
COAL003	36	20.4	1770	88	0.43	7.26
COAL004	35	19.5	1800	125	0.61	4.21

The experiments are performed on the set of 4 test samples of Coal. The thicknesses of the coal sample are different. They are as 37 mm, 44 mm, 36 mm, 35 mm for coal 01, coal 02, coal 03, and coal 04 respectively.

First transmitting transducer & receiving transducer are attached face to face and measures the amplitude of signal. Then sample is placed between transmitting transducer & receiving transducer and time & Voltage are recorded .

III. CONCLUSION

The thickness and transit time affects the velocity of ultrasonic wave in the coal. The observed values of velocities and peak to peak amplitude of different coal sample is mention in the table No.1

As ultrasonic sound wave propagates through coal sample it gets affected based on internal ,composition ,structure and various properties. The ultrasonic sound energy after propagating through coal sample is received by another ultrasonic transducer which is fixed on other side of coal sample. This received signal may be used to extract various properties of coal either by using analog signal processing technique or by using digital signal processing or by using simple statistical method.

As ultrasonic NDT is first time used by the researcher for analyzing the Coal previous literature and data about various parameters are not available, we are trying to extract & co- relate ultrasonic parameter with properties of coal. Table no 1 shows ultrasonic velocity and attenuation measured for coal sample by making the minute observation of ultrasonic pulse velocity and attenuation it may be possible to establish a co-relation between this two with coal properties and to specify the quality of coal. In this work the researcher is tried to develop electronic system based on ultrasonic NDT for evaluation of coal properties.

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