A.Gopichand, ,Dr.M.Muralidhara rao, Prof A.V.N.L.Sharma V.Samuel tony,/ International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 1,Jan-Feb 2012, pp.590-595

Analysis and Estimation of Attenuation Coefficient of Aging EN-19 Steel

A.Gopichand[1], Dr.M.Muralidhara rao[2], Prof .A.V.N.L.Sharma[3], V.Samuel tony[4]

1Associate professor,2 principal, 3.Professor,4.P.G.Student

(Department of Mechanical Engineering, Swarnandhra college of Engineering and Technology, Narsapur-534275,India.)

ABSTRACT

The mechanical properties of in-service facilities are required to evaluate the strength of process equipments. The purpose of this paper is to analyze the relationship between the mechanical properties and the attenuation coefficient of ultrasonic testing. For experimental tests we have selected EN-19 steel as reference. EN-19 steel is subjected to four different isothermal aging at a temperature of 700^{0}C and an original specimen respectively. For these specimens tensile tests, hardness test, impact tests and ultrasonic tests were performed. Attenuation coefficients of ultrasonic testing were determined using Pulse-Echo ultrasonic test. A good analysis and estimation between mechanical properties and attenuation coefficient was found.

Keywords - **non-destructive testing, attenuation coefficient, pulse-echo ultrasonic testing, mechanical properties, aging**

I. INTRODUCTION

For the reliable estimation of remaining life of in-service process equipments, the degradation of material properties of these equipments must be analyzed. These equipments undergo degradation due to prolonged exposure to high temperature. The degradation of mechanical properties affects the safety of operating facilities. Isothermal aging of material varies the EN-19 steel, which is mainly used in various elements like gears, axels, drive shafts, induction hardening pins and high strength shafts. The ultrasonic method is a good technique to evaluate mechanical properties. Ultrasonic attenuation creates relationship between the mechanical properties like tensile strength, hardness. The attenuation of ultrasonic depends on the frequency and grain size of the material. The degradation of mechanical properties affects the safety of operating facilities.

So the evaluation of mechanical property or material degradation is important for structural integrity evaluation. Velocity and attenuation of ultrasonic wave are two important parameters in direct contact ultrasonic technique. The attenuation of ultrasonic wave is sensitive to the grain size of the material and its frequency. The velocity of ultrasonic wave is a function of its frequency or wavelength, and then propagating medium is dispersive.

In this study, we prepared for four different simulated specimens using isothermal aging for each 2 hours, 8 hours, 16 hours and 24 hours at 700˚C respectively and a reference specimen. The effect of aging on the mechanical properties of each specimen has been investigated using tensile tests and hardness tests. Then the mechanical properties were compared with ultrasonic parameter such as attenuation coefficient. From the investigation we are able to confirm that the ultrasonic parameter can be used to evaluate the mechanical properties. During the last few years, the industrial interest has been oriented towards the development of ultrasonic testing in order to achieve high performance with less time. At the same time, there has been an increasing demand for quality caused by an increasing demand for safety, especially in the automotive, process plant equipments by Chang-Sung Seok and Jeong- Pyo Kim, 2005[1].

Ultrasonic refers to any study or application of sound waves that are higher frequency than the human audible range. Ultrasonic waves consist of frequencies greater than 20 KHz and exists in excess of 25 by MHz Sami El Ali [10]. Ultrasonic velocity and attenuation measured using pulse echo technique of frequencies 1 2 and 4 MHz, found that attenuation

coefficient increases with increasing size of casting module, by M A Kenawy, A M Abdel Fattah, N Okasha and M El Gazary,2001 [12]. Mechanical behavior of cryogenically treated en19 steel and reported that increase in tensile strength with a compensation of impact strength also there was a considerable increase in hardness by R Mohan Doss [2].

Tensile and impact test specimens were fabricated subjected to various heat treatment sequences, then mechanically tested for hardness, impact tests, tensile tests by S Z Qamar,2009 [14]. Results showed an increase in tensile strength with a compensation of impact strength also there was a considerable increase in hardness Chang-Sung Seok and Jeong- Pyo Kim, R Mohan Doss, 2005 [1] [2]. Ability to achieve high strength and toughness by heat treatment in a primary advantage of steel alloys B L Ferguson, Z Li and A M Freborg, 2005 [13] steel develops an excellent combination of tensile strength, impact strength and ductility which is very attractive for structural usage by O.O.Daramola, B O Adewuyi and I O Oladele, 2010 [16].

2.ULTRASONIC TESTING

Ultrasonic testing (UT) is a non-destructive inspection method that uses high frequency sound waves (ultrasound) that are above the range of human hearing, to measure geometric and physical properties in materials. Ultrasound travels in different materials at different speeds (velocity). However, the speed of sound propagation in a given material is a constant

2.1 ULTRASONIC ATTENUATION

Measurement of ultrasonic attenuation in cast steel components will provide useful information in the assessment of the grain size and thereby on the effect of heat treatment. The grain size of as-cast steel is large and high attenuation is caused by the ultrasonic beam being scattered by the large grains. In the fully heat treated condition, when the temperature of the heat treatment exceeds the transformation temperature, the as-cast grain structure is recrystallized. The grain size of fully heat treated material is small and its ultrasonic attenuation is low. The predominant factor in attenuation measurement is the relationship between the ultrasonic wavelength and the grain size.

2.2 PULSE ECHO TEST METHOD

A pulse echo configuration was used in this work with transducer and all signals were taken at normal incidence on the interface of specimen. In this inspection mode, a single transmitter-receiver transducer scans along the material surface capturing signals that have been reflected from the back surface, or from discontinuities (interfaces or defects) in the material. Additional echoes are produced due to the presence of discontinuities within the region being interrogated. In the presence of a defect, the incident pulse is almost totally reflected at the interface with little or no ultrasonic signal transmitted to the material below the defect.

The arrival time of these echoes provides information as to the through-thickness location of the associated defect. This method is effective in interrogating the bond line between a uniform thickness skin and a non-metallic core substructure. The principle is to monitor a signal in a pre-set time window, or gate. The gate may be positioned between the front surface echo and before the back surface reflection, or actually on the back-wall echo.

The amplitude of the signal in this gate indicates the level of acoustic impedance discontinuity in the material at that location. This method of operation can be carried out in an immersion tank with deionised water as the ultrasonic couplant or by using a contact transducer. For the contact mode, water is replaced by gel, oil or grease couplant

2.3 MESUREMENT OF ATTENUATION COEFFICIENT

. The attenuation coefficient can be expressed as

$$A=A_0e^{-\alpha Z}$$

In this expression,

A_0 is the unattenuated amplitude or original amplitude of the propagating wave at some location,

A is the reduced amplitude,

Z is the distance travelled from initial location,

α is the attenuation coefficient of the wave traveling in the z-direction.

The term **e** is the exponential (or Napier's constant) which is equal to approximately 2.71828

3.AGING Alloys must be kept at elevated temperature for hours to allow precipitation to take place. This time delay is called aging.

4.EXPERIMENTAL PROCEDURE

4.1Material selection

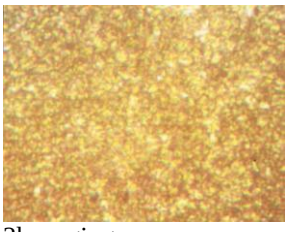
For experimental procedure we have selected EN-19 steel. This EN-19 steel is regularly available in the shape of blocks and is widely used in components for medium and large cross sections requiring low tensile strength, heavy forging in the normalized condition for automatic engineering, gear and engine construction, crankshafts, high strength shafts, drive shafts, high tensile bolts axes, connecting rods, propeller shaft joints, rifle barrels, induction hardened pins.

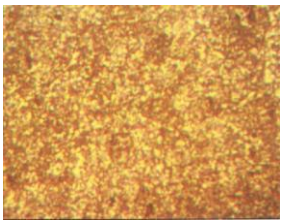
.4.2 Aging of EN-19 steel

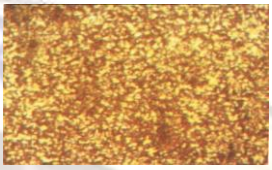
In this study, we have prepared for four different simulated specimens of EN 19 steel using isothermally aging for each 2, 8, 16 and 24 hours at 700˚C respectively and a reference specimen. The effect of the aging period on the mechanical properties of each specimen has been investigated using tensile test, hardness and the impact test. Then the mechanical properties were compared with ultrasonic parameters such as attenuation.

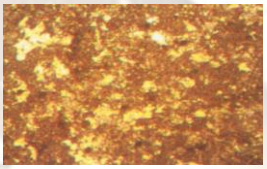
4.3Micro structure of EN 19 Steel

Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25× magnification. The microstructure of a material which can be broadly classified
into metallic, polymeric, ceramic and composite, can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, wear resistance, and so on, which in turn govern the application of these materials in industrial practice. To examine the average diameter of grain size, a microscope was used.
Etchant used is 4% NITAL. Nital is a solution of alcohol and nitric acid commonly used for routine etching of metals. It is especially suitable for revealing the microstructure of carbon steels. Magnification: 100X, type of equipment used is meta scan metallurgical microscope.


2hrs aging


8hrs aging


16 hrs aging

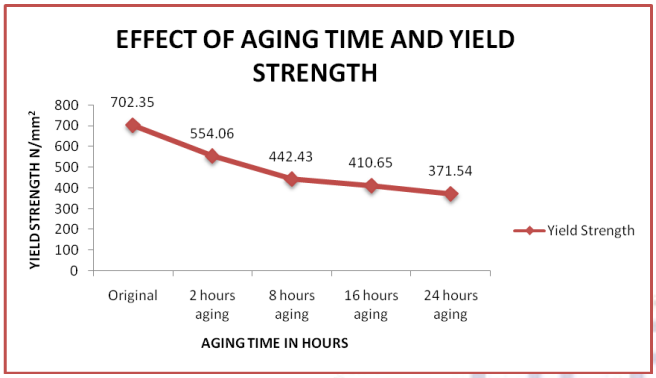

24 hrs aging
Grainsize is increasing with aging.

4.4 Mechanical properties

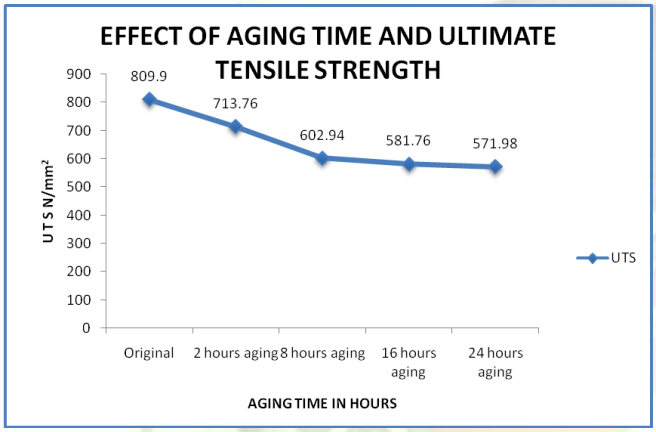
TENSILE PROPERTIES

Tensile test was performed using a universal testing machine at room temperature. EN-19 steel of different aged specimens are tested . From the test results, yield strength, ultimate tensile strength and uniform elongation were determined. From the experimental test results, we can observe that the material strength decreased as the aging time increased.

Universal Testing Machine & specimen



Aging time Vs Yield Strength

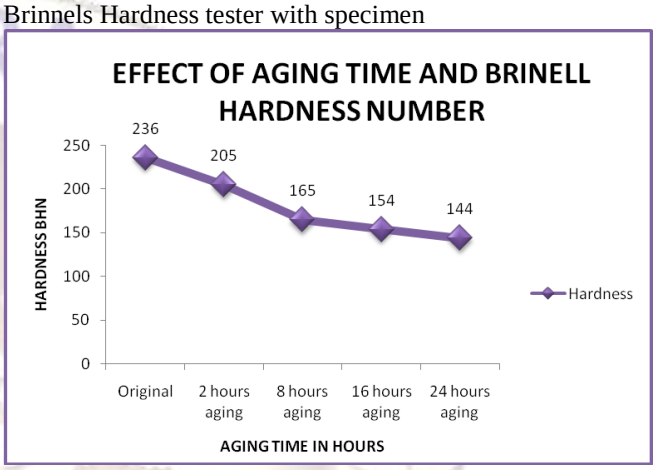


Aging time Vs Ultimate tensile strength

HARDNESS

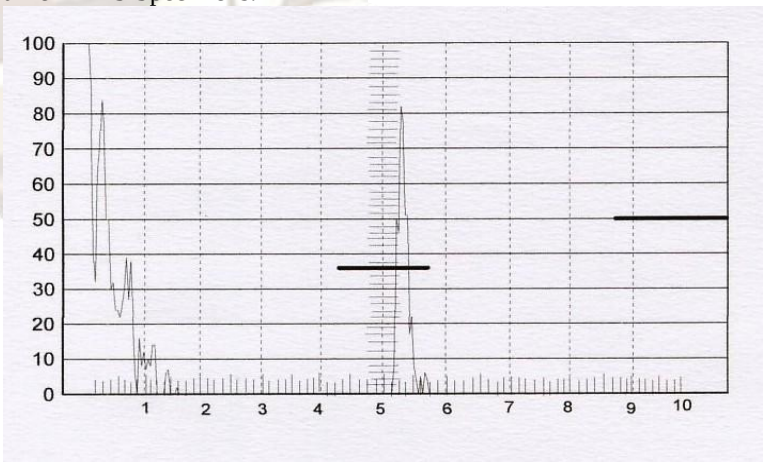
Brinell hardness tester was used for hardness testing.The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. The Brinell method involves ball penetrators of different diameters (always in mm), which are pressed with a certain load onto a smooth and even surface for a certain amount of time (10 to 15 seconds).

Brinnels Hardness tester with specimen

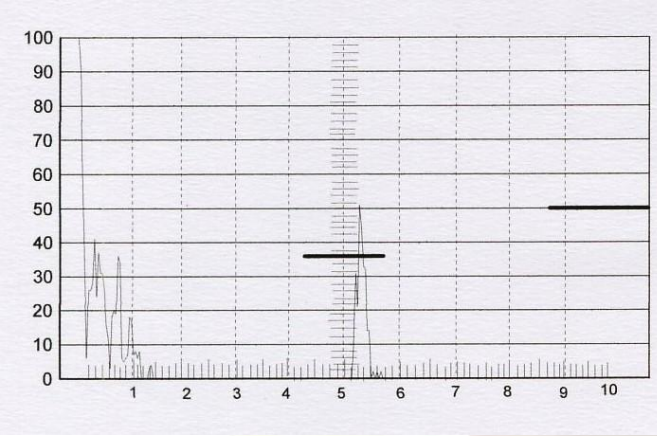


4.5Determination of Attneuation coefficient.

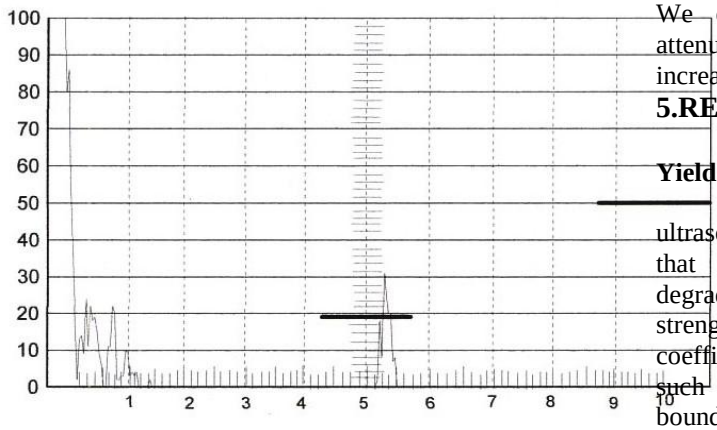
The attenuation coefficient is a quantity that characterizes how easily a material or medium can be penetrated by a beam of light, sound, particles, or other energy or matter. In this study the Probe type normal probe piezo electric crystal and Frequency of probe is 6 MHz. .The transducer displays are used to to evaluate attenuation coefficient for different aging time EN-19 Specimens.



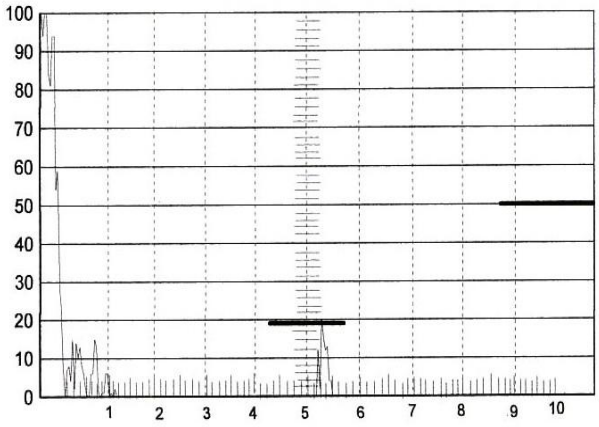
2HOURS AGING



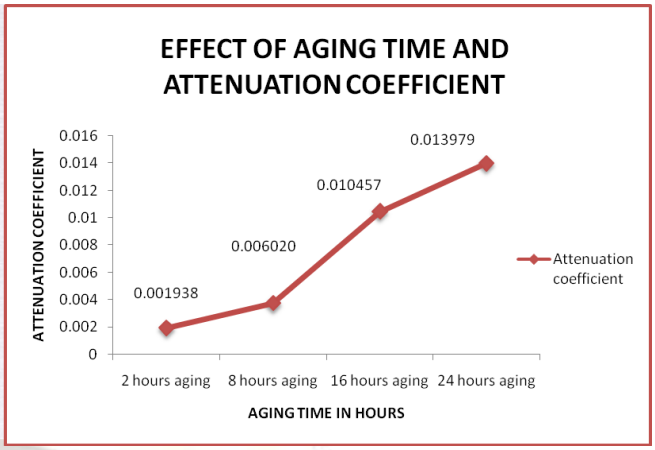
8HOURS AGING



16 HOURS AGING



24 HOURS AGING

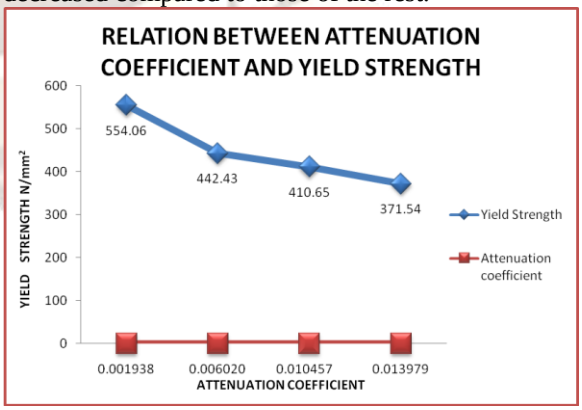


We can observe that aging hours increased attenuation coefficient of ultrasonic wave is also increased

5.RESULTS AND DISCUSSIONS

Yield Strength and Attenuation Coefficient.

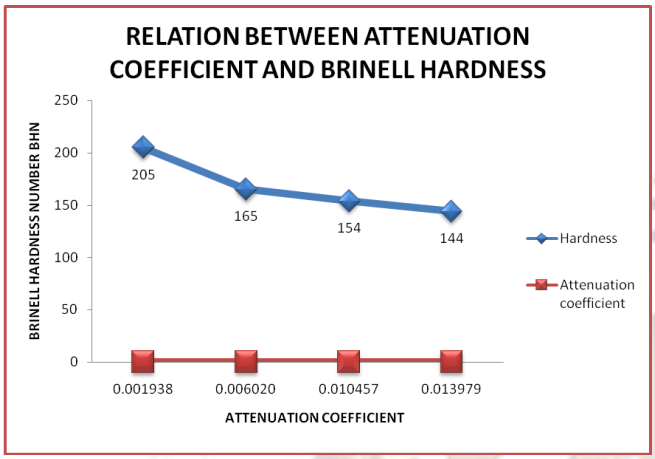
The relation between yield strength and ultrasonic parameter is shown in graph. It is known that the attenuation coefficients increased as degradation occurs with the decreasing of yield strength of material. The increase of attenuation coefficient is dependent on the scattering components such as grain size and precipitates at grain boundaries. The weakness of material causes the decrease of the yield strength. The decrease of the yield strength can be interpreted as the appearance of the specific substances and the intergrannular brittleness due to the formation of the chemical compound at grain boundaries. Especially, the yield trength of the 24 hours aging material steeply decreased compared to those of the rest.



Hardness and Attenuation coefficient

The relation between ultrasonic parameters and Brinell hardness is shown in the figure. The

reason for the decrease of the material hardness can also be interpreted as intergranular brittleness contrary to the increase of ultrasonic parameters.



6.CONCLUSION

To investigate the mechanical properties using ultrasonic technique, we prepared for five different simulated specimens of EN 19 STEEL by isothermal aging heat treatment. By comparing various mechanical properties obtained from tensile and impact test with ultrasonic parameters of these specimens such as attenuation, the following conclusions were obtained.

1. The yield strength and the Brinell hardness decreased as the aging time increased.
2. Attenuation coefficients of an ultrasonic signal increased as the aging time increased.
3. The attenuation of ultrasonic test is sensitive and will be a good parameter to evaluate the mechanical properties such as yield strength, ultimate tensile strength, impact test results and hardness.

REFERENCES

[1] "Studies on the correlation between mechanical properties and ultrasonic parameters of aging 1 Cr-1Mo-0.25V steel" by Chang-Sung Seok and Jeong-Pyo Kim, journal of mechanical science and technology, vol 19, no 2, pp 487~495, 2005.

[2] "Mechanical behavior of cryogenically treated en19 steel" by R. Mohan doss, international journal of power control signal and computation, vol 1, no, 4

[3] "Ultrasonic testing of steel castings" by J. D. Lavender by steel founders society of America.

[4] "Standard test methods and definitions for mechanical testing of steel products" SA 370, American Society for Testing and Materials, pp 617 ~639.

[5] ASTM E 399-90, 1995, "standard test method for plane-strain fracture toughness of metallic materials" annual book of ASTM standard.

[6] "Guide book for the fabrication of non-destructive testing (NDT) test specimens" by IAEA 2001.

[7] "Pulse echo ultrasound imaging systems, performance tests and criteria"- published in AAPM by the American Institute of Physics Report number 8, November 1980.

[8] "A comparison study of the pulse echo ultrasonic's and the through transmission" by G. Wrobel, S. Pawlak, volume 22 issue 2 June 2007 in journal of achievements in materials and manufacturing engineering.

[9] "Understanding of materials state and its degradation using non-linear ultrasound approaches" by Dr. Krishnan Balasubramaniam, submitted in AOARD AFOSR Tokyo, Japan.

[10] "Ultrasonic wave propagation review" by Sami El Ali

[11] "Piezo ceramic materials for ultrasonic probes" by A M Abdel Fattah, M G S Ali, N Z El Syed, Gharieb.A.Ali in Egypt journal for solids, vol 28, no 2, 2005

[12] "Ultrasonic measurement and metallurgical properties of ductile cast iron" by M A Kenawy, A M Abdel Fattah, N.Okasha and M ElGazary in Egypt journal for solids, vol 24, no 2, 2001

[13] "Modeling heat treatment of steel parts" by B L Ferguson, Z Li and A M Freborg in Computational Materials Science 34 (2005) 274–281 Elsevier.

[14] "Effect of heat treatment on mechanical properties of H11 tool steel" by S Z Qamar in Journal of achievements in materials and manufacturing engineering vol 35 issue 2 august 2009.

[15] "Effects of heat treatment on the mechanical properties of rolled medium carbon steel" by O.O. Daramola, B.O. Adewuyi and I.O. Oladele in Journal of Minerals & Materials Characterization & Engineering, Vol. 9 No.8, pp.693-708, 2010.