Review Paper on Characterization of Casting Material by Ultrasonic Techniques

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Abstract

A review provided about non-destructive testing (NDT) method that is ultrasonic technique for the characterization of casting material. The review considers the capabilities of Ultrasonic Testing (UT) with respect to advantages and disadvantages of this method. Then, method categorized based on their intrinsic characteristics and their applications. The aim of this study is the investigation of the capability of ultrasonic technique in assessment of the structure and properties of nodular cast iron and to provide additional data concerning the particulars of the use ultrasonic velocity and attenuation measurements for quality control of different grades of ductile iron either in the as-cast condition or after heat treatment. In the measurements, first the directional dependence of velocity and apparent attenuation can be investigated. Ultrasonic velocity and apparent attenuation measurements can be carried out at various testing frequencies to observe the effect of the probe frequency. The nodularity status can be examined by metallographic investigations and hardness tests were performed. Finally, the results of ultrasonic velocity measurements, metallographic investigations and mechanical tests can be compared. Thus; Ultrasonic Technique is effective quality control tool which can be used for characterization of casting materials.

Keywords: Ultrasonic, Ductile Iron, Graphite Nodularity, Sound Velocity, Attenuation

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I. INTRODUCTION

There are varieties of methods to evaluate materials or components and non-destructive methods are an important category of them with many applications. The field of Non-Destructive Evaluation (NDE) or Non-Destructive Testing (NDT) involves the identification and characterization of damages on the surface and interior of materials without cutting apart or otherwise altering the material (Lockard, 2015). In other words, NDT refers to the evaluation and inspection process of materials or components for characterization or finding defects and flaws in comparison with some standards without altering the original attributes or harming the object being tested. NDT techniques provide a cost effective means of testing of a sample for individual investigation or may be applied on the whole material for checking in a production quality control system (Newswire, 2013). A wide variety of NDT methods plays major roles in testing of casting parts (Scott and Scala, 1982). This paper reviews ultrasonic NDT method for evaluation of different properties followed by categorizing them and discussion about their advantages and disadvantages.

II. ULTRASONIC TESTING

Ultrasonic Testing (UT) evaluation system consists of a transmitter and receiver circuit, transducer tool, and display devices. Based on the information carried by the signal, crack location, flaw size, its orientation and other characteristics could be achieved (Lu, 2010). Advantages of ultrasonic testing include speed of scan, good resolution and flaw detecting capabilities, and ability of use in the field. Disadvantages include difficulty of set up, needed skill to scan a part accurately, and the need of test sample to insure accurate testing. This type of testing is excellent for use in an assembly line where the same part design must test repeatedly. There are two approaches of ultrasonic NDT generally used in different applications; pulse echo and through transmission approaches. Both of these approaches use high frequency sound waves on the order of 1-50 MHz to detect internal flaws in a material (Garney, 2006).

Ultrasonic testing conducted in three modes, transmission, reflection, and back scattering. Each of which uses a range of transducers, coupling agents, and frequencies (Stonawski 2008). Pulse echo ultrasonic method can readily locate defects in homogeneous materials. In this method, the operator more concerns about the transit time of the wave and the energy loss due to attenuation and wave scattering on flaws. It helps to locate inconsistency in a material whether it is homogeneous or heterogeneous (Warnemuende, 2006). For large defect detection, location, and imaging purposes, and quality control, ultrasonic pulse velocity

measurements are quite suitable (Oguma et al. 2012). The through transmission ultrasonic method is different from conventional ultrasonic methods. This method keeps the transducer and receiver off the surface and at a fixed distance away from the sample. This is particularly advantageous when complex geometries do not allow for the contact of a traditional transducer and receiver to the surface of the part.

The most commonly used indicators of properties are wave propagation velocity and amplitude (or energy) loss. Some of the testing methods described here in only address one property, while others, more versatile, may measure two or three (Ducharne et al. 2015). Most applications consider only the pulse velocity and relate it to different parameters. Considering energy loss can discover a few additional characteristics of a material (Karabutov and Podymova, 2014). A number of authors have studied the method of pulse attenuation analysis (El-Sabbagh et al. 2013; Genovés et al. 2015). Scattering, absorption and geometric are three parameters that affect the attenuation. Small discontinuities like grain boundaries are the source of scattering.

III. PROPERTY PREDICTION USING ULTRASONIC

Nanekar et al. (1992) focused on flaws detection and material characterization by ultrasonic's. They explained various ultrasonic testing parameters for material characterization; also characterization of mechanical properties by ultrasonic testing is also explained. So this paper gives brief description about material characterization. Kenawy et al. (2001) focused on the ultrasonic technique for defect detection in ductile cast iron and metallurgical property of ductile cast iron. The relation between carbon equivalent and nodularity is also discussed, they also discussed about casting module and ultrasonic velocity of ductile cast iron. Bockus (2006) focused on property and microstructure of cast iron product, and also concluded that by increasing percentage of the values Mn, Cr, Cu and Sb the hardness and tensile strength of cast iron are increased and decreased by the decreasing the values of carbon equivalent contents.

Lohith (2009) described various nondestructive testing (NDT), in this technique one of the most important technique is explained i.e. ultrasonic testing. They gave brief description of this technique. They also explained ultrasonic velocities in solids and liquids. Sagar (2008) discussed various NDT techniques and their principles for detecting defects in cast materials; they explained various NDT techniques i.e. liquid penetrant inspection (LPI), magnetic penetrant inspection (MPI), computed tomography (CT) and (UT) ultrasonic testing. They also gave focus on brief description of ultrasonic method for detecting defects in cast materials. Pandey et al. (2010) focused on the material characterization techniques, like nondestructive testing (NDT) and destructive testings (DT), but gave brief description about ultrasonic method, for material characterization.

Kenawy et al. (2001) discussed some mechanical properties like hardness, toughness, and tensile strength; also some grades are explained like pearlite and ferrite grades. And ultrasonic technique is also explained, they used pulse echo method for the ultrasonic velocity and attenuation measurement for ductile cast iron; also the relation between nodule count and mechanical property like tensile strength and hardness of cast materials are also explained. Khalili et al. (2018) described the performance of the A1, S0, SH0, SH1, M-SKIP and CHIME inspection methods for detecting sharp and gradual defects was established via numerical prediction with the selective experimental validation. Also recommends a combination of two or more methods when inspecting, for corrosion at inaccessible locations such pipe supports. Maggi et al. (2011) described technical aspects of v1 and v2 reference standard block certification and calibration. This paper also presented many applications of ultrasonic nondestructive testing.

Gholizadeh (2016) reviewed various nondestructive testing methods for evaluation of composite materials by categorizing their advantages and disadvantages. This paper concluded that use of nondestructive testing for identifying and evaluating faults or destructive defects. Uzun and bilge (2015) described hardness of welded steels and correlations of measurements of an accepted hardness test techniques with ultrasonic wave velocity. Finally concluded that, the ultrasonic waves are capable of effectively determining the hardness variations in industrial applications. Victoria et al. (2015) described the ultrasonic characterization and hardness of austenitic stainless steel in thermal variations, paper shows correlation studies on ultrasonic longitudinal and shear wave velocity with hardness which indicates that the longitudinal velocity plays important role in extent of sensitization than shear velocity. Khan et al. (2015) described the ultrasonic nondestructive testing technique for material characterization and evaluation of material properties of AISI 316L stainless steel. This paper concluded that empirical results are deduced in form of relationship between ultrasonic testing parameters and mechanical properties of material.

Kawalec (2014) discussed the high alloyed white cast iron ,that are modified with different components , which are titanium, lanthanum and aluminum, stromium with obtained alloys; many studies are done which are discussed in this paper like metallographic examinations, mechanical testing and also hardness. Hafiz (2001) discussed about SG iron and mechanical properties like, tensile strength, hardness, toughness .Correlations between various properties are also investigated. They also explained about fractography and different matrix structure. Dawson (1999) focused on the mechanical properties and physical properties of compacted graphite iron and microstructural considerations like nodularity; also some material properties of graphite iron also discussed i.e. poison's ratio, thermal expansions. This explained properties are useful for engine design. Voronkova (2006) gave detailed description about ultrasonic testing for flaw detection, also explained some important mechanical characteristics.

IV. MICROSTRUCTURE PREDICTION USING ULTRASONIC

Oliver et al. (2006) discussed the samples morphology and its associated ultrasonic velocity also explained ultrasonic velocity range associated with graphite form of scrap tested in this study. And it was found too wide for the ultrasonic testing which is used

as quality control methodology for selection of grey cast iron based upon the microstructure. Sarkimo et al. (2007) gave detailed description of manufacturing of nodular cast iron inserts and various defect types in cast iron inserts. Also some equipment's are discussed for ultrasonic studies; inspection possibilities and modeling cases are explained. Heinrietz et al. (2014) discussed the fatigue strength of spheroidal cast iron, also fatigue strength of various materials are given like GJS 400, GJS 450, GJS 700. Derivations of porosities in specimens are also described.

Hatate et al. (2012) explained the detailed description of graphite nodularity and ultrasonic velocity of cast iron, and some accuracy improving methods are also discussed. Bhat et al. (2018) described the preconditioning by alloys like Al, Zr, Ca-FeSi having significant effect on graphite nodule size distribution in spheroidal graphite iron. They concluded that graphite nodule count and their size distribution must be considered for shrinkage control in SG-iron. Bono et al. (2018) presented fundamental principles of resonant acoustic method and its application for testing nodularity, paper also describes case study on ductile iron for testing nodularity. Freitas et al. (2009) described the microstructural characteristics of steel phases and their selection according to their distinct microstructure; ferrite, pearlite and martensite respectively. This paper also given information about metallography and hardness testing.

Toozandehjani et al. (2015) reviewed that the evaluation of microstructure and ultrasonic properties, various ultrasonic testing parameters and applications of ultrasonic techniques are also described. Researchers concluded that, UT can be used for evaluation of mechanical properties of various materials and microstructural variations. Griffin et al. (2005) described ultrasonic velocity measurement and microstructure evaluation of gray iron by using ultrasonic techniques and statistical analysis. Also investigates mechanical property relationships like Brinell hardness and ultrasonic velocity. Researchers concluded that irons with higher graphite and pearlite content having lower ultrasonic velocity values, and higher ultrasonic velocity where associated with lower free carbon contents.

Kumar et al. (2003) discussed the correlation of ultrasonic velocity with hardness and volume fractions of ferrite and martensite; characterizations of microstructure in 9% chromium ferrite steels are also explained by using ultrasonic measurements. Radzikowska (2001) gave detailed description of metallography and microstructure. They also explained preparation of micro examination they gave some methods of micro-examination like chemical etching and standard etchant has been used, they also explained about microstructure of graphite in which he told that, the eutectic graphite cell has a continuous graphite skeleton, but on metallographic cross section the three dimensional nature is not obvious. Also the information about microstructure matrix is explained. Sangame et al. (2013) presented the cup thermal analysis for ductile cast iron. Also the nodularity and nodule count of cast iron and its effects are also discussed. They also focused on inoculation process, i.e. Inoculant is substance added to metal or alloy in small quantity that causes significant change in structure and property.

V. CONCLUSIONS

This paper reviewed ultrasonic testing NDT method for casting evaluation by categorizing their advantages and disadvantages. The non-destructive testing has become more crucial and demanding. Factors such as efficiency and safety should be used in analyzing the best method to be used. Furthermore, the method chosen should minimize the costs incurred in the operation. It is based on methods that depend on the use of physical values to determine the characteristics of materials. In addition, non-destructive tests use physical principles to identify and evaluate faults or destructive defects. Ultrasonic techniques are sensitive to the changes in the graphite morphology, thus they can also be used to predict the mechanical properties. The ultrasonic techniques eliminate the need for preparation and destructive testing of specimens; furthermore, they can be carried out in a few minutes and are cost effective. Thus; Ultrasonic Technique is effective quality control tool which can be used for characterization of various casting materials.

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