Preliminary Evaluation of Material & Components through Ultrasonic Technique for Quality Prediction.

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ABSTRACT:

Testing and evaluation of materials and allied products has one primary objective. It is to make sure that parts being produced actually meet all required specifications established by customer. Use of Non-destructive testing and evaluation (NDT&E) as a means of quality control permits the industries for better quality products. Sound detection of faults in materials is one of the oldest Non-destructive methods. In case of pot, earthen or metallic, it is possible to detect whether there is a flaw from sound emitted when the pot is tapped. The useful range of ultrasonic for Non-destructive testing of metals falls within range of 100kc/s to 20-25 Mc/s. The normal range for testing is 0.5-5 Mc/s. In flaw detection this frequency is usually in the range of one million to six million times per second (1MHz to 6MHz). Assessment of structural integrity requires three inputs, viz, i. Mechanical properties (yield strength, fracture toughness etc.) ii. Stress (applied as well as residual), iii. Flaw characteristics (type, shape, size, orientation and location). Ultrasonics are extensively used for flaw characterization. Of late, it has also shown great potential in assessment of mechanical properties and residual stresses. Ultrasonic parameters, on which material characterizations are based, include velocity (V), attenuation (α), back scatter (B) and resonance frequency (f). Although theoretically, there should not be any limitations to Ultrasonic testing provided right technique is adopted for right job. In reality, it exists in many spheres till today. This is mainly due to basic reasons : (a) surface irregularity and geometry of the test object and (b) coarse grain metallurgical structure. In fact, management of industries want or expect to solve all their non-destructive testing problems by ultrasonic alone without fully knowing its limitations. This creates a psychological effect to the inspector/operator who in turn conceals facts and prepares test reports to their satisfaction. Any person practicing ultrasonic aware, how manipulation can be made in test results. While ignorance or lack of knowledge often gives wrong interpretation of indications, many a time, operator deliberately obtains to mislead the inspecting officer, who observes the CRT screen display without practicing by himself.

Keywords: structural integrity, attenuation, back scatter, flaw, orientation, residual stress.
INTRODUCTION

Non Destructive Evaluation and Characterization of worked materials and structures using ultrasonic has acquired great importance in modern engineering practices for ensuring their quality, overall safety and reliability. Economics reason forcing extension of life of gaining components and structure of worked materials have also provided momentum to the development of their in-situ and in service inspection, characterization by using ultrasonic technique vis-à-vis evaluation of defects, as well as microstructure and stresses.

Non-destructive testing of ultrasonic involves incorporation of physical principles for determining flaws, dimensional variation, microstructural features and mechanical properties of worked materials without impairing their usefulness. The technique may be considered a three stage process from basic principle:[1]

1. Detection of flaw or determination of physico-chemical properties by some signal, like a pulse or image on CRT screen or as diffraction grating on the hologram.
2. Interpretation of the signal to understand its physical meaning such as precise location, nature, size and distribution of flaws, or microstructural characterization and the mechanical properties.
3. An erudite decision on the significance of the test results.

The purpose of the present paper is to discuss:

i. The non-destructive applications of ultrasonic for determining structural integrity, microstructural features and mechanical properties of worked materials.

ii. Limitations of the system.

iii. How to overcome all these limitations.[2]

ULTRASONIC IN FOUNDRY, FORGE ALLIED INDUSTRIES:

Sound waves more than frequency 20KH/sec is called Ultrasonic, which can propagate through matter, so used for testing the discontinuity present in any of the components casted, forged or worked. The most widely spread method is the manual ultrasonic inspection where a hand held probe is moved in some pre-arranged, scanning path and the pulse echo is observed on the CRT screen. The screen has an A-scan display with horizontal base line indicating elapsed time and height of vertical deflection (called
indications, pipes or blips) representing intensities on echoes. Flaw locator (depth) is determined by calibrated time based and the flaw size determined by comparing height of echo with that of discontinuity of known size and shape. Selection of ultrasonic probe in regard to its type, diameter and frequency is dependent on the type of material, shape of the test piece and sensitivity (minimum flaw size). In practical testing (ultrasonic), first frequency is selected and then the size of the probe. Generally, low frequency probe is first used for better probability of detecting the flaw followed by high frequency probe for their characterization, e.g Shape and size. [3]

Typical casting defects are non-metallic inclusions, porosity, shrinkage cavities, cold shuts, hot tears (shrink cracks) cold or stress cracks, blow holes or inhomogeneity. All these defects can be tested ultrasonically by proper selection of probes (normal or angle) frequency, and attenuation.

![Schematic Diagram of ultrasonic display.](image)

<table>
<thead>
<tr>
<th>Type of material</th>
<th>Test Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Metals</td>
<td>0.5 - 2 MHZ</td>
</tr>
<tr>
<td>Presses / Forged metals</td>
<td>2 - 6 MHZ</td>
</tr>
<tr>
<td>Ceramics (for electrical insulators)</td>
<td>2 - 4 MHZ</td>
</tr>
<tr>
<td>Weld</td>
<td>2 - 5 MHZ</td>
</tr>
</tbody>
</table>
Concrete & similar materials  
(Special equipment required)  
50 - 200 MHZ  

<table>
<thead>
<tr>
<th>Synthetic materials</th>
<th>1 - 4 MHZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Depending upon coupling characteristics)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Desirable test frequency [4]

**MEASUREMENT OF DISCONTINUITY SIZE BY ULTRASONIC:**

The size of discontinuity in the form of a circular disk smaller than the cross section of the ultrasonic beam is related to the amplitude of the ultrasonic reflected from it by the following equation:

\[ A = A_o \]

Where, \( A \) = amplitude of the sound beam reflected from the circular disk

\( A_o \) = amplitude of the ultrasound at the transducer

\( S_s \) = surface area of the transducer

\( S_f \) = surface area of the circular disk

\( d \) = distance between the transducer and the circular disk

\( \beta \) = attenuation coefficient

\( \lambda \) = ultrasonic wavelength

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<table>
<thead>
<tr>
<th>Sharp echo</th>
<th>Cracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo not as sharpen cracks</td>
<td>Slag springers</td>
</tr>
</tbody>
</table>

[ID55]
The desirable frequency as a function of the type of material is summarized in table 1. In addition to this it has been observed that coarse grains, cause severe attenuation and pronounced scattering and the back echo disappears. In such cases, lower frequency is preferred.

<table>
<thead>
<tr>
<th>Plate Thickness</th>
<th>Beam Angle (in degree)</th>
<th>Skip Distance(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-30</td>
<td>70</td>
<td>30-165</td>
</tr>
<tr>
<td>30-60</td>
<td>60</td>
<td>105-210</td>
</tr>
<tr>
<td>Above 60</td>
<td>45</td>
<td>Above 120</td>
</tr>
</tbody>
</table>

Table 3: Typical specifications for weld materials [6]

Ultrasonic offer very useful and versatile non-destructive methods for investigating other properties like residual stress, hardness, grain size, measurement, microstructure and elastic constants. Similarly, material characterization by ultrasonic techniques is very common now-a-days.

**Some of the forging defects and testing methods [7]**

Typical forging defects may be

- Primary shrinkage cavity
- Secondary shrinkage cavity
- Nonmetallic inclusions such as Si and Al oxides
- Foreign bodies such as pieces of furnace lining
- Flakes (Hydrogen embrittlement cracked)
- Segregation

Testing off hot forging has not found much application in practice due to strong heat radiation. For all these reasons the testing of large forgings is usually done after final finishing. The surface roughness for
testing of forging should not exceed from 10-12.5 mm. The testing technique depends on the pattern of the forging grain flow.

**Limitations**

Although theoretically, there should not be any limitation to ultrasonic testing provided right technique is adopted for right job. In reality it exists in many sphere till today. This is mainly due to two basic reasons:

a) Surface irregularity and geometry of the test

b) Coarse grain metallurgical structure.

For example, if keyhole is present either in a casting or a forging we will get spurious indications. Similarly, spurious indication will be coming due to loose crystals in the probe, long job with small diameter, surface irregularities and bottom holes. So far as grain size is concerned, low frequency is preferable when grain size is coarse (Cast Structure) that means attenuation is more. [8-9]

**POOR KNOWLEDGE IN THE TRADE, HOW TO ARREST IT!**

In fact, management of the industries want or expect to solve all their non-destructive testing problems by ultrasonic alone without fully knowing its limitations. This creates a psychological effect to the inspector/operator who in turn conceals facts and prepares test report to their satisfaction. Any person practicing ultrasonic is aware, how manipulation can be made in the test results. While ignorance or lack of knowledge often gives wrong interpretation of indications, many a time, operator how manipulation can be made in the test results. While ignorance or lack of knowledge often gives wrong interpretation of indications, many a time, operator deliberately obtains to mislead the inspecting officer, who observes the CRT screen display without practicing by himself.

All these problems can be arrested, with the availability of digitized and computerized image processing techniques, for evaluation of flow characteristics which was found to be a limitation in convention UT. At the same time the inspecting officer must undergo proper training by approved bodies like ASNT, ISNT for operation of the systems and flaw interpretation.

**Conclusion**
In this paper ultrasonic techniques used for inspection of castings, forgings and weldments are discussed. Since it is not practically possible to extend the techniques, the extent of the discussion are kept to the minimum.

Reference:


[4]. Non-destructive testing by R. Halmshaw, Metallurgy and Material science series.


[7]. “Non-destructive testing & evaluation of cast and forged materials” by Mr. B. Mallik et al., P 202, 29-30th September proceeding of National Conference on Quality Control in Metallurgical Industries.

