ULTRASONIC INSPECTION – A REVIEW

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Abstract:
All mechanical components are subjected to some kind of forces, stresses which tend to formulate surface or sub-surface defects. Defects over time due to wear and because of its structural integrity, to maintain its usability, it's necessary to go for testing devices rather than manual testing for better results. However, manual testing results in many limitations: high training cost, training procedure over a long period of time and many more. So in order to detect the accurate location and size of flaws, cracks or defects in materials, it's better to use sound waves with high frequency to evaluate for discontinuities without causing damage to the material, which is called NDT. Common NDT methods are Ultrasonic, Radiographic, Eddy current. In this paper various research studies on UI method is reviewed with major focus on straight beam (pulse transit-time, transmission) & angle beam techniques. The scope for further research (QDNE) in this area is also discussed.

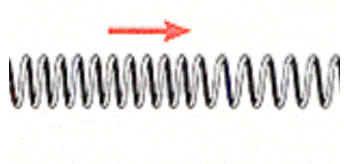
Keywords: NDT (Non Destructive Testing), UI (Ultrasonic Inspection), Straight beam, angle beam, pulse transit-time, through transmission, QDNE (Quantitative non-destructive evaluation)

1. Introduction:

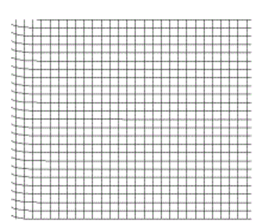
ULTRASONIC INSPECTION is a non-destructive method in which beams of high frequency sound waves are introduced into materials for the detection of surface and subsurface flaws in the material. The sound waves travel through the material with some attenuation and reflected at interfaces. The reflected beam is analyzed to define the presence and location of flaws and discontinuities. And detailed images can produced with automated systems.

The two most commonly use types sound waves used are longitudinal and shear waves. As shown in adjacent fig.

Longitudinal waves



Shear waves



Sound is introduced into the material using an ultrasonic transducer that converts electrical impulses from the UT machine into sound waves, and then converts returning sound back into electric impulses that can be displayed as a visual representation on a digital or LCD screen.

2. Physics of ultrasound:

2.1 Wavelength:

It is the distance between two successive crest of a wave. Since wavelength and frequency inter-related, changing the frequency when the sound velocity is fixed will result in change in the wavelength of the sound. The wavelength of the ultrasound used has significant effect on the probability of detecting a discontinuity (discontinuity must be larger than one-half of the wavelength to stand a reasonable chance of being detected)

2.2 Frequency:

Frequency is the number of a repeating event per unit time. The most common sound frequencies used in UT are between 1.0 and 10.0 MHz, which are too high to be heard and do not travel through air. The lower frequencies have greater penetrating power but less sensitivity, while the higher frequencies don't penetrate as deeply but can detect smaller indications.

2.3 Intensity:

Physical parameter that describes amount of energy through a unit cross sectional area of beam each second. It describes the loudness of sound in dB.

2.4 Acoustic impedance:

When ultrasonic waves traveling through one medium impinge on the boundary of a second medium, a portion of the incident acoustic energy is reflected back from the boundary while the remaining energy is transmitted into the second medium. The characteristic that determines the amount of reflection is the acoustic impedance of the two materials on either side of the boundary. If the impedances of the two materials are equal, there will be no reflection.

2.5 Sensitivity & Resolution:

Sensitivity and Resolution are two terms which describe a technique's ability to locate flaws. Sensitivity is the ability to locate small discontinuities. Resolution is the ability of the system to locate discontinuities that are close together within the material or located near the part surface. These two generally increases with higher frequency (shorter wavelengths).

2.6 Speed:

Sound does travel at different speeds in different materials. This is because the mass of atomic particles and the spring constants are different for different materials.

2.7 Attenuation:

When sound travels through a medium its intensity diminishes with distance. However, all materials produce an effect which further weakens the sound because of scattering and absorption phenomenon. Scattering is the reflection of the sound in directions other than its original direction of propagation. Absorption is the conversion of the sound energy to other forms of energy. The combined effect of scattering and absorption is called attenuation.

3. Inspection methods:

According to the nature of flaw different inspection methods are used. Materials with cracks parallel to the surface –straight beam technique, and for the laminar flaws -angle beam technique is adopted.

3.1 Straight Beam:

Straight beam inspection uses longitudinal waves to evaluate the test piece. If the sound hits an internal reflector, the sound from that reflector will reflect to the transducer faster than the sound coming back from the back-wall of the part due to the shorter distance from the transducer. This results in a screen display. As shown in fig(1)

There are two different inspecting methods use straight beam techniques

1. Pulse transit-time
2. pulse through transmission

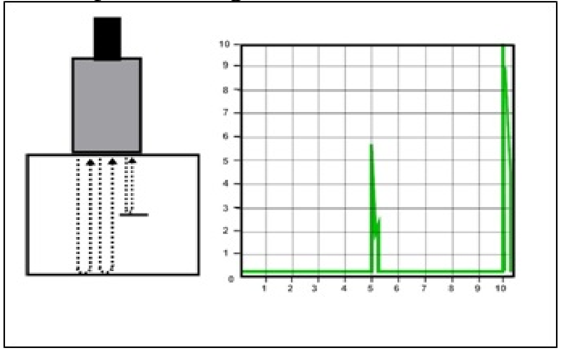


Figure 1

3.11 Pulse transit-time method:

Pulse transit-time method is more useful in these days since it requires one sided access for inspection. Here, transmitter (T) generates an ultrasonic pulsed wave which is reflected by a defect or the back wall of the specimen, and obtained by the receiver (R). The received signal is displayed on a screen. As shown in fig (2).

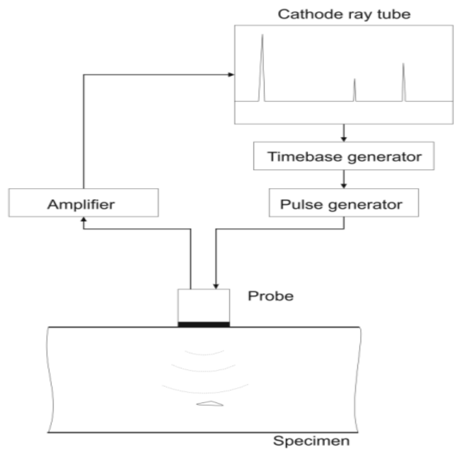


Figure 2

The pulse generator sends an electric pulse to the transmitter probe, which produces an ultrasonic pulse. This ultrasonic wave spreads into the specimen and is reflected to the receiver, which transforms the wave into an electric signal. This signal is then send to the amplifier and from there to the cathode ray (CR) tube, which displays the signal as peaks. The time base generator produces a high frequency wave and makes the spot move across the CR tube.

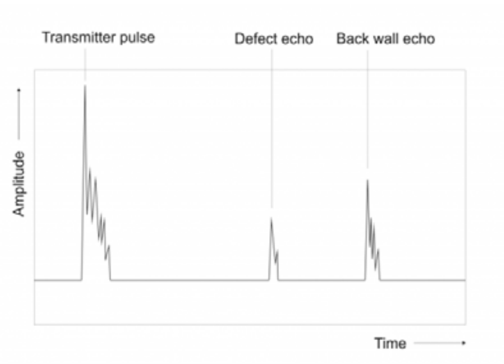


Figure 3

As shown in fig (3). The first peak on the display represents the generated ultrasonic pulse. The ultrasonic wave travels through the specimen until it is reflected or scattered by a surface. The reflected part of the wave can be seen as peak on CR tube. The other part of the wave continues to the back wall of the specimen and will be reflected there

In modern displays the velocity of sound can be entered and the display shows the vertical distance of the peak instead of the time on the X axis. The depth of a defect or the back wall can be read directly from the display.

3.12 Through-transmission:

The through-transmission technique with the transmitter (T) and receiver(R) separately on opposite sides of the specimen. As shown in fig(4)

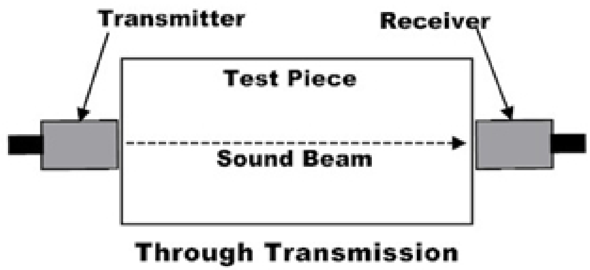


Figure 4

Through transmission inspections are performed using two transducers, the transmitting transducer sends sound through the part and the receiving transducer receives the sound. Reflectors in the part will cause a reduction in the amount of sound reaching the receiver so that the screen presentation will show a signal with a lower amplitude (screen height). If a flaw is detected, the signal R is lost or reduced as shown in cases B and C of Figure (5).

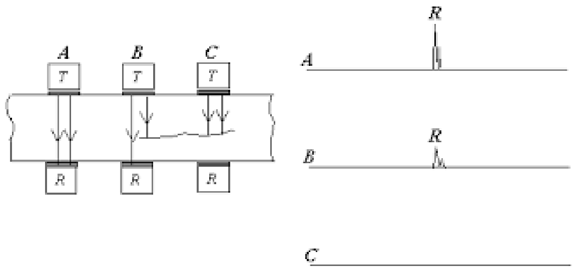


Figure 5

3.2 Angle Beam:

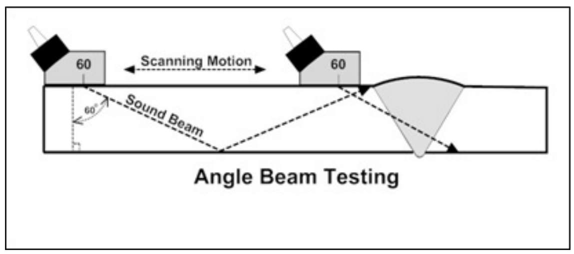


Figure 6

Angle beam inspection uses the same type of transducer but it is mounted on an angled wedge

that is designed to transmit the sound beam into the part at a known angle. The most commonly used inspection angles are 45^o, 60^o and 70^o, with the angle being calculated up from a line drawn through the thickness of the part (not the part surface). A 60^o probe is shown in fig (6).
If the frequency and wedge angle is not specified by the governing code or specification, it is up to the operator to select a combination that will adequately inspect the part being tested.

In angle beam inspections, the transducer and wedge combination is moved back and forth towards the weld so that the sound beam passes through the full volume of the weld. As with straight beam inspections, reflectors aligned more or less perpendicular to the sound beam will send sound back to the transducer and are displayed on the screen.

3.3 Immersion Testing:

Immersion Testing is a technique where the part is immersed in a tank of water with the water being used as the coupling medium to allow the sound beam to travel between the transducer and the part. The UT machine is mounted on a movable platform (a "bridge") on the side of the tank so it can travel down the length of the tank. The transducer is swivel-mounted on at the bottom of a waterproof tube that can be raised, lowered and moved across the tank. The bridge and tube movement permits the transducer to be moved on the X-, Y- and Z-axes. All directions of travel are gear driven so the transducer can be moved in accurate increments in all directions, and the swivel allows the transducer to be oriented so the sound beam enters the part at the required angle. Round test parts are often mounted on powered rollers so that the part can be rotated as the transducer travels down its length, allowing the full circumference to be tested. Multiple transducers can be used at the same time so that multiple scans can be performed.

4. Recent innovations in ultrasonic testing devices: (11.04.16 -SONOTEC):

Ultra sonic flaw detectors have a trigonometric function that allows for fast and accurate location determination of flaws when performing shear wave inspections. Cathode ray tubes have been replaced with LED or LCD screens. These screens, in most cases, are extremely easy to view in a wide range of ambient lighting. Screens can be adjusted for brightness, contrast, and on some instruments even the colour of the screen and signal can be selected.
Some recent innovations, Nowadays preventive maintenance is an even more important value driver in industry. Therefore, HANNOVER MESSE is devoting a special exhibition area to the topic of "Predictive Maintenance" in 2016, in which SONOTEC will present the new SONAPHONE and will show how companies can save energy and improve total production efficiency with ultrasonic testing devices.

SONAPHONE -The goal was to develop the first user-friendly ultrasonic testing device, which combines new measuring technology, innovative sensors and intelligent software for preventive maintenance,". The ultrasonic specialist from Halle (Saale) has been developing and selling ultrasonic testing devices for 25 years for leak detection in compressed air and gas systems, monitoring of bearings, detection of partial discharges and checking valves and steam traps. The mobile ultrasonic testing devices make a significant contribution to increased plant safety and availability and are part of the basic equipment of many maintenance technicians.

5. Applicability:

Some of the major types of equipment that are ultrasonically inspected for the presence of flaws are:

1. *Mill components:* Rolls, shafts, drives, and press columns
2. *Power equipment:* Turbine forgings, generator rotors, and pressure vessels
3. *Jet engine parts:* Turbine and compressor forgings, and gear blanks
4. *Aircraft components:* Forging stock, frame sections, and honeycomb sandwich assemblies
5. *Machinery materials:* Die blocks, tool steels, and drill pipe
6. *Railroad parts:* Axles, wheels, track, and welded rail
7. *Automotive parts:* Forgings, ductile castings, and brazed and/or welded components.

6. Future direction:

The use of NDE to improve the productivity of manufacturing processes. Quantitative non-destructive evaluation (QNDE) both increases the amount of information about failure modes and the speed with which information can be obtained and facilitates the development of in-line measurements for process control.

In industries manufacturing flaws will never be completely eliminated and material damage will continue to occur in-service so continual development of flaw detection and characterization techniques is necessary. Advanced simulation tools that are designed for inspect-ability will contribute to increase the number and types of engineering applications of NDE.

7. Conclusion:

An attempt has been done to put up all the different ultrasonic inspection methods. And also applications of UT machine has been listed for industrial purpose use. Recent innovations in the testing machines like sonaphone(the user friendly device) is also outlined. The scope for further work in this area has been discussed.

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