Behavior of Ultrasound Energy in the Presence of Obstacle

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Abstract - In this paper, we study the behavior of a ultrasound energy in presence of an obstacle. The ultrasound signal of 50kHz is passed through the concrete cubes of different size and grade. The concrete cubes are embedded with the obstacles of different densities. Using Mat lab and fundamentals of ultrasound energy, energy curves are drawn and area under the curve is calculated. The area under the energy curve is absorbed when passed through an obstacle. This shows that the energy is decreased when ultrasound signal from one medium to another.

***Key Words*:** Concrete, Obstacle, Ultrasound, Ultrasonic, Ultrasound energy, Mat lab, acoustic attenuation, Ultrasonic signal.

1.INTRODUCTION

Ultrasonic waves are sound waves that are beyond the normal hearing range of the human beings. The frequency of such waves are above 20kHz. This waves have similar properties to that of sound waves. This waves are used in various field such as Medicine, Industries and construction. It is used for Non-Destructive Evaluation in the field of construction.

Ultrasonic Pulse Velocity is usually used in the structural health monitoring to determine the quality of concrete. But this method deals with the overall quality but cannot find any foreign objects present in the concrete. To overcome this drawback, we use ultrasound energy to distinguish obstacles in the concrete.

The signal processing software such as Mat lab, lab view, etc., makes it simple for us to derive energy from the signal. In this paper, we use Mat lab to calculate energy of the ultrasonic signal.

1.1 Principle of ultrasonic wave:

There are three principles of ultrasonics . They are Law of reflection, refraction and shadow method. The law of reflection states that when a wave is passed through material with two different media a part of wave is reflected and the remaining flow through the second material but not in direction same as incident wave. The law of refraction states that that "the angle made by the incident wave with the normal plane to the interface is the same as the angle made by the reflected wave with the normal plane to the interface of material". The detection of decrease in energy of Ultrasonic beam due to absorption of energy by flaw. This involves the transformation of energy due to internal friction of defect or failure to transfer energy across the air gap of defect. This is known as the shadow method. In this paper, we use the shadow method.

1.2 Methods of transmission

To assess the condition of a concrete the transistor time of high frequency sound waves are used. ASTM standard C-597 talks about ultrasonic testing procedures. Two separate transducers are required to measure sound velocity in non-homogenous materials as concrete. One is for transmitting and the other is for receiving. Sound velocity is calculated by measuring the time required to transmit over a known path length. The uniformity in concrete is established by the measurement of average sound velocity through the concrete. There are three approaches for measuring the sound velocity in concrete. They are direct, indirect and semi-direct. Direct method is method in which we keep both the transducers opposite sides of object, Indirect method is a method in which we place both the transducers on the same side of the object. In Semi-direct method, we place transducers on adjacent sides of object. Here, we use the direct method.

1.3 Properties of Ultrasonic wave:

Ultrasonic waves while passing through materials experience resistance by the stress front or pressure in the passage of waves. This resistance depends on the property of the material.

1.3.1. Acoustic Impedance:

Acoustic Impedance is the resistance experienced by Ultrasound to the passage. It is denoted by Z.

$Z= \rho \times V$ [eq. 1]

Where ρ is density of the material and V is the Velocity of the sound wave.

1.3.2. Acoustic Attenuation:

Attenuation is the property of material which reduces the energy as the ultrasound wave passes through it. Higher the attenuation, lower the penetrability of the wave. Large amounts of this attenuation leads to loss of back wall reflection.

The main Phenomena due to this attenuation are Scattering, Diffusion, Viscous damping losses and Relaxation losses. Scattering and diffusion are caused due to the wave motion of ultrasound. Viscous damping and relaxation losses are caused by the stressing of atoms in material. We use acoustic attenuation in this paper.

1.4 Data Collection:

The signal is transmitted through the transducer and received is collected through the digital oscilloscope. Generally, the data is collected and represented in three formats. They are A-scan, B-Scan and C-Scan.

A-Scan represents the strength of the signal or Amplitude with the time as the function. This represents the waveform of the signal. The energy depends on the square of the amplitude. Hence, this setup is used in the ultrasound energy method. B-Scan presents the change in the time of flight of signal with respect to that of the distance. It displays the time of flight on the Y-Axis and Scan distance on the X-Axis. This representation is used in the ultrasonic pulse echo method. C-Scan displays the features of the test specimen such as location and size. It is like the plan view of the specimen. It gives the image of the feature of the defects or specimen. This is generally used in the ultrasound tomography method. In this paper, we use B-Scan.

1.5 Energy:

Vibratory waves are introduced into the medium at frequencies above 20kHz to produce ultrasonic waves. The energy produced by these waves is known as ultrasound energy.

As per the Moradi-Marani, Farid, et al. Construction and Building Materials,2014, the energy can be calculated through the following equation

$$E = \sum_{n}^{i} \frac{1}{2} (A_i + A_{i+1})^2 . dt \qquad \text{[eq. 2]}$$

E is Energy of Ultrasonic wave

A is Amplitude of Ultrasonic wave

t' is time travelled by the wave

The Mat lab code is written using eq.2 and energy curves are drawn. Since, the energy is sensitive to minor changes, we study the behaviour of ultrasound energy to an obstacle present in the concrete.

2. EXPERIMENT

2.1 Materials

According to IS 12269, OPC grade 53 cement is taken into consideration. A locally accessible coarse aggregate mixture of 60% 10mm and 40% 20mm with a specific gravity of 2.83 is employed. The fine aggregate utilised has a specific gravity of 2.6. In M40 concrete, Conplast SP – 430 is utilised as a superplasticizer. The M20, M30, and M40 concrete are designed with obstacles in accordance with IS 10262: 2019.

Thermocol and plywood with 50mm thickness and 110 mm in length and breadth are used as obstacles in 220mm cubes, and thermocol and plywood with 50mm thickness and 160mm in length and breadth are used as obstacles in 320mm cubes. The 16mm rod is 34 mm from the right and 75 mm from the back edge of the concrete cube in 220 mm. The 20mm rod is 75 mm from the concrete cube's left edge and 40 mm from the front edge. The 32mm rod is 30mm from the left edge of the concrete cube and 70mm from the back edge. The 16mm rod is 80mm from the right and 95mm from the back edge of the concrete cube in 320 mm. The 20mm rod is 40mm from the left edge of the concrete cube and 75mm from the front edge. The 32mm rod is 60mm from the left edge of the concrete cube and 100mm from the back edge.

Table 1. Area under energy curves of the ultrasonic signals passed through Concrete cubes of 220mm

Part of testing	Area under Energy curve (J-s)		
	M20	M30	M40
Sampling interval	**4.00E-05**	**2.00E-04**	**1.00E-06**
without obstacle	2.02E-05	3.72E-04	2.91E-03
without plywood	2.64E-05	9.52E-04	2.68E-03
with plywood	2.65E-05	1.18E-03	2.63E-03
without thermocol	2.59E-05	3.00E-04	2.79E-03
with thermocol	2.13E-05	3.92E-06	2.82E-03

2.2 Procedure:

Portable Ultrasonic Non-destructive Digital Indicating Tester (PUNDIT) transducers with a frequency of 54 kHz are saved on opposing edges of the cube as mentioned in 1.2 for direct transmission. BNC cables are used to link the transmitter and receiver to the PUNDIT. BNC cables are used to connect

PUNDIT to the digital oscilloscope. The signal from the digital oscilloscope is sent to the computer through USB. Within the digital oscilloscope, the output signal is captured. The amplitude and temporal components are calculated using B-scan, as described in 1.4. MATLAB is used to import the amplitude, time components, and sample frequency. Equation 2 is used to determine the signal's energy, and the mat lab code is used to draw the energy curve.

Repeat the experiment on a concrete cube with no obstacles, a concrete cube with and without plywood, with and without thermocol, and rods of 16mm, 20mm, and 32mm in diameter. Calculate the area beneath the energy curve using the MATLAB 'trapz' function and compare the area beneath the curves in tables 1 and 2.

3. RESULTS

Table 2. Area under energy curves of the ultrasonic signals passed through Concrete cubes of 220mm - Rods

Part of testing	Area under Energy curve (J-s)		
	M20	**M30**	**M40**
Sampling interval	**1.00E-06**	**1.00E-06**	**1.00E-06**
without rods	2.93E-03	2.82E-03	2.91E-03
with 16mm Rod	2.92E-03	2.94E-03	2.81E-03
with 20mm Rod	2.73E-03	2.95E-03	2.88E-03
with 32mm Rod	2.81E-03	2.98E-03	2.74E-03

Table 1 and 2 shows the area under the energy curve of the ultrasonic signal passed through the M20, M30 and M40 concrete cube of 220mm dimension with and without foreign objects in it . Table 3 and 4 shows the area under the energy curve of the ultrasonic signal passed through the M20, M30 and M40 concrete cube of 320mm dimension with and without foreign objects in it.

The table 1 and 3 shows that the area under the energy curve when passed through an obstacle is lesser that of the concrete without an obstacle. This displays that the absorption of the energy of ultrasonic wave when passed through a concrete block with obstacle. Table 2 and 4 depicts the area under the energy curves that pass through the concrete with rods of 16mm, 20mm and 32 mm are almost similar in all grades of concrete. So this shows that the reinforcement does not affect the energy as other two obstacles.

Table 3. Area under energy curves of the ultrasonic signals passed through Concrete cubes of 320mm

Part of testing	Area under Energy curve (J-s)		
	M20	**M30**	**M40**
Sampling interval	**2.00E-04**	**2.00E-04**	**1.00E-06**
without obstacle	3.50E-04	7.32E-04	2.81E-03
without plywood	2.47E-04	6.66E-04	2.68E-03
with plywood	1.48E-06	6.78E-04	2.60E-03
without thermocol	3.10E-04	7.11E-04	2.72E-03
with thermocol	2.53E-04	6.91E-04	2.70E-03

Table 4. Area under energy curves of the ultrasonic signals passed through Concrete cubes of 320mm - Rods

Part of testing	Area under Energy curve (J-s)		
	M20	**M30**	**M40**
Sampling interval	**2.00E-04**	**2.00E-04**	**1.00E-06**
without rods	3.50E-04	7.32E-04	2.81E-03
with 16mm Rod	2.52E-04	6.79E-04	2.84E-03
with 20mm Rod	2.53E-04	6.95E-04	2.68E-03
with 32mm Rod	2.19E-04	7.25E-04	2.60E-03

4. CONCLUSION

The area under the energy curve is reduced when passed through an obstacle other than reinforcement. The reinforcement does not affect the energy. Hence, the energy of an ultrasonic wave is absorbed when passed through the concrete block with a foreign object. This method can be used to detect foreign objects present in the concrete as well as reinforced concrete structures.

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