Application of 6db Drop Technique to Estimate the Width of Sub Assembly Ring Top Using Pulse Echo Ultrasonic Technique

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***Abstract*—This paper deals with the estimation of width of top of sub assembly ring using Pulse Echo Ultrasonic Technique. Due to the effect of beam spread, the ring appears to be magnified in its width. 6db drop in amplitude and 6db drop from edges have been applied to estimate width of the object using two different transducers kept at different distances from the object. Better results are obtained for the transducer kept close to the object but in the far field region. Error of 0.8mm and error of 0.6mm has been obtained with the two techniques of 6db drop in amplitude and from 6db drop from edges.**

Keyword- Pulse Echo, 6db drop, SAFT, Ultrasonics, Width

I. INTRODUCTION

In Prototype Fast Breeder Reactor (PFBR), liquid sodium is used in which the fuel sub assemblies are submerged. Due to high temperature conditions and irradiations, deformations called growth and bowing occur on the sub assembly rings, which must be detected before the start of next fuel cycle. Pulse Echo Ultrasonic Testing is the only feasible technique which could be employed to detect these anomalies. The reason being Pulse echo ultrasonic technique requires single side access. In pulse echo technique, a single transducer performs as both transmitter and receiver. Pulse Echo technique operates both in contact mode and immersion mode. Immersion transducers are available which can be used under such high temperature conditions. An under-sodium scanner had been deployed in the reactor to detect the interspaces' between CCPM (Core Cover Plate Mechanism) and Sub-Assembly (S/A) tops for any protruding S/A [1]. The system has also been used to detect bowing and growth by imaging the SA tops by means of C Scans obtained from Pulse Echo technique [2].

This paper explores the feasibility of measurement of width (shell thickness) of the SA top using A Scans. The idea behind measurement of width of the SA top is to determine the centre point of the region under measurement. Similarly centre points could be obtained across different regions across the circumference of the SA top. If minimum of three centre points are found and these points form the focus of a circle, then this would indicate that SA top has not undergone any deformation. It is important that the width obtained across different regions must have the same precision.

Pulse Echo technique has been widely used to determine thickness of materials, detection of flaws and estimation of dimensions of the flaws. The ultrasonic wave emitted by the transducer gets reflected by the top surface of the object, portion of the waves propagate through the material, gets reflected at the flaws, if any, propagates further and gets reflected at the back surface of the material. The receiver receives the reflected waves the display is in the form of A Scan, B Scan or C Scan. The amount of ultrasonic energy received by the transducer as a function of time is represented in A Scan. A typical A Scan consists of transmitted wave or initial pulse, reflected echoes from the top surface of the specimen and defects (if any), and finally the reflected echo from the back wall of the specimen known as back wall echo., Normally, the A Scan is used to measure the thickness (depth) of the specimen. The thickness can be obtained from the distance between the first reflected echo and the back wall echo. The transducer is made to move in a horizontal direction along the top surface of the object and emits pulses at particular steps in the direction of its movement.[3-6]. The sound field that emerges out of the transducer spreads out as it progresses into the material. This is known as beam spread. Due to the effect of beam spread, the transducer detects the object even when the transducer is away from the object. This gives the effect of increased width. In the near field, due to acoustical variations, detection of flaws becomes very difficult. The region just beyond the near field is the far field where the sound wave is well behaved and at its maximum strength. Detection of flaws is easy in the far field region. If the flaws can be detected accurately, then the determination of size of the flaw is the next requisite. It is important to note that in the far field region, the sound pressure is maximum along the centre line of the transducer. The beam spread or the beam diameter depends on the sound path distance, frequency of the transducer, diameter of the transducer. The standard techniques adopted for estimation of length of flaw are 6db drop technique, 20db drop techniques [7]. 6db amplitude drop technique defines the defect length as the half (6db) of the maximum amplitude obtained while the transducer is scanned over the flaw.[8] The principle of length sizing using -6db from flaw edges involves identification of last significant amplitude obtained while transducer is traversed across the flaw as the edges. From the edges, -6db reduction of the amplitude would yield the length of the flaw[9].

Due to beam spread and due to the height at which the transducer is placed above the object, both the edges are simultaneously detected by the transducer. Only when the transducer is at extreme positions from the object, one of the edge is detected. The echoes that emerge out from both the edges are not separated but overlap each other. The envelope of the A Scan is obtained using Hilbert transform. If the edges could be identified the width could be estimated.

This paper is organized into five sections. In Section II the hardware system used for collection of data is explained. Section III deals with the methodology adopted in determination of the width of the specimen. In Section IV, results obtained have been tabulated and analysis has been done. Conclusions and drawbacks of the technique have been discussed in Section V.

II. DATA ACQUISITION

A typical automated Ultrasonic system consists of an immersion tank, sensor system and recording system. Transducer, actuators, stepper motors and a programmable logic controller comprise the sensor system. The immersion tank with the transducer attached to the actuator is shown in Fig.1.

Fig.1.Immersion Tank and Sensor sytem

The recording system typically consists of signal conditioning unit, Cathode Ray Tube for display, PC with software for storing the data .The single normal beam unfocused transducer of 10mm diameter of frequency 5 MHz is attached to the actuator. Though there are two stepper motors for horizontal and vertical movement of the transducer, the vertical position of the transducer is kept constant. The stepper motor causes the movement of the transducer through the actuator. The number of pulses to be given to cause the required movement of the stepper motor and thereby the transducer is fed through the computer to the PLC. The transducer is scanned along the surface of the specimen kept immersed in water bath.

The transducer is made to move horizontally at constant steps over the surface of the object. The object is the subassembly ring head. At each point of stop, it sends ultrasonic pulses and receives the reflected echoes in the form of A Scans. The electrical signals are digitised with a sampling frequency of 100 MHz. and 50000 samples are stored for each A Scan. The transducer is kept at a height of 125mm from the object in the water column. The transducer is kept at an initial position where the edge of the beam begins to detect the object. From this position, the transducer is moved with a spatial resolution of 0.5mm and for every step, A Scans are recorded. The transducer is moved till the edge of the beam stops detecting the object. The movement of the transducer is depicted in Fig.2. The transducer is moved with step size of 0.5mm and 45 A Scans have been acquired.

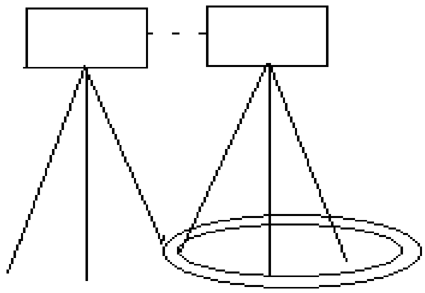

Fig.2. Movement of transducer for detection of object.

Another normal beam focused transducer of frequency 5 MHz and diameter 6mm is placed at a height of 30mm from the same object in the water column. The transducer is moved over the surface of the object with a spatial resolution of 0.5mm and 9 A Scans have been acquired.

III. METHODOLOGY

The envelope of the A Scans is obtained using Hilbert transform and the envelope of the A Scans obtained at different positions have been shown in the Fig.3

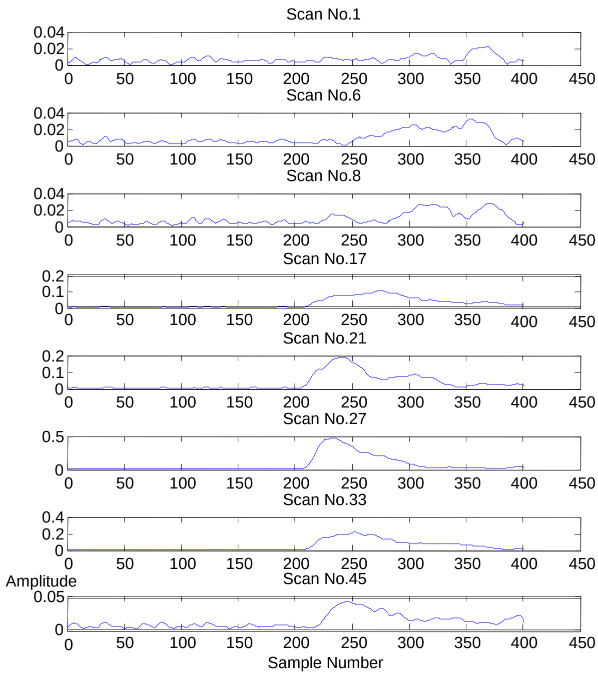

Fig.3. Envelope of A Scans at different positions of the transducer of 10mm diameter.

The horizontal axis of the above A Scans indicate the sample number and the vertical axis indicates the amplitude of the A Scan. The Scan No.1 indicates the detection of one of the edges of the object by the edge of the beam. As the transducer moves closer towards the object, the inner edge becomes more prominent, which is indicated by the increase in amplitude. This is seen in Scan no.6 and 8. As the transducer moves closer, the entire beam falls on the object; this is seen in Scan No.17 and 21. As the transducer moves away from the object, the centre line of the beam hits the outer edge of the transducer. This is indicated by the maximum peak in the Scan no.27. As the transducer continues to move further away from the object, the edge of the beam hits the object which is seen in Scan no.33 and 45. By sharp observation of the amplitude of the A Scans, it is observed that the edges of the object are marked by Scan No.8 and Scan No.27. This means that the transducer has traversed a path of 9mm to detect the edges of the object. This means that the actual size of 3.2mm is seen as 9mm

Another normal beam focussed transducer of 6mm diameter and frequency 5 MHz is placed at a height of 30mm and A Scans have been recorded. The A Scans obtained with the second transducer has been shown in the Fig.4.

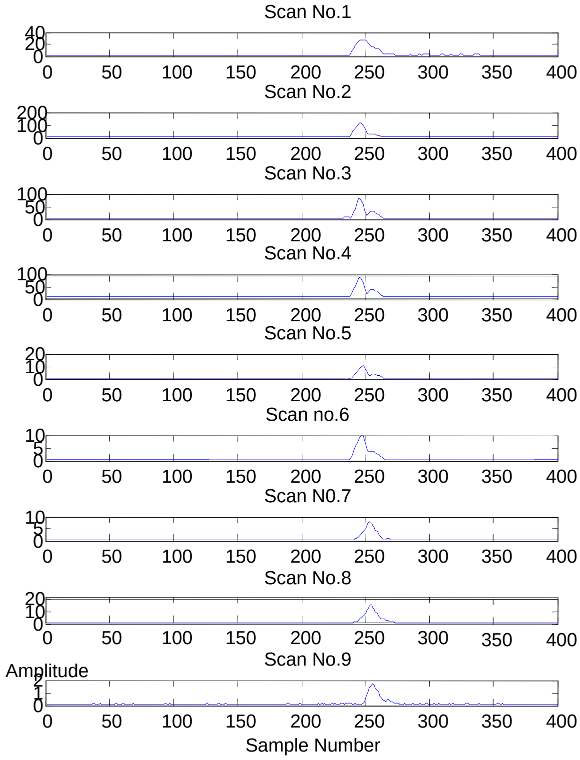

Fig.4 The A Scans recorded with transducer of 6mm diameter

The horizontal axis indicates the sample number and the vertical axis indicates the amplitude. The Scan No.1 has detected the outer edge of the object. The amplitude is maximum in scan no.2 where the centre line of transducer hits the outer edge of the object. As the transducer is moved closer, the other edge is also detected which is seen in Scan No.3,4,5and 6. In Scan No.7, only the inner edge has been detected. The amplitude of Scan No.7,8 and 9 is small as the major portion of the beam sees the bottom of the immersion tank and gets reflected. Hence the backwall echo would be of higher amplitude. The maximum amplitude of the Scan No.8 could indicate the centre line of transducer hitting the inner edge. Therefore the transducer has moved 8 steps or a distance of 3.5mm to detect the edges of the object, which is in close agreement with the actual width of the object.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A sub assembly ring top of 3.2mm width has been taken as the object under study and conventional pulse echo ultrasonic technique has been applied to estimate its width. Two transducers of diameters 10mm and 6mm respectively, both of 5MHz frequency have been used. The first transducer has been placed at a distance of 125mm from the object and A Scans have been obtained. The second transducer has been placed at a distance of 30mm from the object and A Scans have been obtained. 6db drop technique from the maximum value and 6db drop from the edges has been applied to estimate the width.

The maximum amplitude of each A Scan obtained is noted and the highest among them is taken as the reference. From that A Scan, half the amplitude of the A Scan on either side of the reference is noted. By application of 6db amplitude drop, the width of the object is found to be 4mm. The distance traversed by the transducer is 24^{th} Scan to 33^{rd} Scan, ie 8 positions. By multiplying with the spatial resolution, we get the width as 4mm. Thus an error of +0.8mm is obtained. Application of 6db drop from edges yielded the width as 13mm, an error too high.

Similarly with the data obtained using second transducer, maximum amplitude of each A Scan is noted, the data is interpolated using cubic interpolation technique for 0.1mm. By application of 6db drop technique, the width, in this case, is found to be 1.5mm. Thus we find that this technique has undersized the width. As we have determined the edges, 6db drop from the edges is applied and the width is now found to be 3.8mm, an error of 0.6mm.

V.CONCLUSIONS

The transducer diameter is larger than the width object under consideration. The techniques of 6db drop in amplitude and 6db drop from edges have been applied to estimate the width of top of sub assembly ring. In the case where the sound path is high, both the techniques have oversized the width but 6db drop in amplitude has given less error.

In the case where sound path is low, but in far field region, the 6db drop in amplitude has undersized the width but application of 6db drop from edges has given less error.

TABLE I: Tabulation of Results for 10mm unfocussed transducer

Technique Applied	Distance between object and transducer	Estimated width	Error
6db drop in amplitude	125mm	4mm	0.8mm
6db drop from edges	125mm	13mm	9.8mm

TABLE II: Tabulation of Results for 6mm focussed transducer

Technique Applied	Distance between object and transducer	Estimated width	Error
6db drop in amplitude	30mm	1.5mm	1.7mm
6db drop from edges	30mm	3.8mm	0.6mm

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