Study on Indication pattern in Time of Flight Diffraction technique

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Abstract

Unlike other Non-destructive Ultrasonic techniques like Conventional UT & Phased Array, it is difficult to distinguish flaws by its pattern shown in ToFD technique. If any indication is found in ToFD scan of weld, then to identify its type we have to perform Conventional UT at that location. What if we can directly identify the type of flaw by just looking at its pattern in the image? We prepared a joint by welding and put artificial and known defects in it at different locations and scanned it with ToFD. The flaws can now be judged by their pattern.

In addition to that this paper provide information in regards to effect of different parameters of ToFD technique like Frequency, PCS(Probe Center Separation) on defect detectability in near surface area of the weld.

The purpose of this paper is to enable the reader to classify the flaws by looking at their pattern in ToFD image without further supplementing it with conventional UT.

Keywords: ToFD, UT, PCS
Introduction:

ToFD works on the principle that sound is diffracted from the tips of the flaws and it travels in all directions in the metal. It is detected by the receiver. Some portion of the incident sound is also reflected from the flaw and it may or may not be detected by the receiver. The image of the flaw is formed by combining these two reflected and diffracted portions of the sound. From this image we can calculate the exact size and location of the flaw inside the metal, but it doesn’t clearly shows any information about the type of flaw. So a study was conducted by preparing a joint of thickness 60mm and having length 5m. In this joint some of the common defects like slag, porosity, lack of fusion and crack were intentionally made during welding. Their patterns generated in ToFD were studied and we came to our conclusion that there is certain similarity in pattern which distinguishes one type of flaw from the other. By analysing that pattern we get more surety about the type of flaw.

Case Study:

The study started by preparing several joints having embedded defects. The joints were made in pipes and plates. The weld edge preparation is depicted in the Picture (a).

Following were the type of flaws generated in the welds:

1. Slag inclusion
2. Porosity
3. Lack of fusion
4. Crack
The different patterns formed by these defects in ToFD are visualised below.

1. **Slag Inclusion**: Slag has irregular surface due to which its image formed in ToFD shows multiple diffraction signals (parabolas) over its entire length as shown in Picture (a) to Picture (d).

![Picture (a)](image1.png) ![Picture (b)](image2.png) ![Picture (c)](image3.png) ![Picture (d)](image4.png)

2. **Porosity**: Porosity may be in cluster or individual. Due to its negligible length, small diffraction signals (parabolas) appear close to each other in ToFD image as shown in Picture (e) and Picture (f). Individual parabolas having negligible length have also major chances of being originated from porosity.

![Picture (e)](image5.png) ![Picture (f)](image6.png)
3. **Lack of fusion:** Lack of fusion has a smooth reflective surface due to which its image shows a continuous line over its length with two diffraction signals at its two end points. See the Picture (g) and Picture (h).

![Picture (g)](image1)

![Picture (h)](image2)

4. **Crack:** Crack has no specific pattern, but it can be said that its pattern is very distinguishable from every other type of flaw.

![Picture (i)](image3)

Now talking about the detectability in near surface area of the weld. In this area the blind zone of ToFD imposes restrictions due to which surface and near surface defects may or may not be detected. The depth of blind zone may vary and the factors affecting this are:

1. PCS(Probe Centre Separation)
2. Frequency of the sound
To show the effect of these factors a block was prepared with four Flat bottom holes having dia 1.5mm and depths varying from 2mm to 8mm as shown in the Picture (j).

This block was scanned with varying PCS and varying frequency and the effect is visualized below.

1. **Effect of PCS (Probe Centre Separation):**
   - **Scan #1:** 70degree, 10MHz with 60mm PCS.
     As shown in the Picture (k), Hole 1 is barely visible due to the blind zone of ToFD. The other holes are getting separate from the lateral wave due to their greater depth.

   ![Picture (k): ToFD 70deg, 10 MHz, 60PCS scan](image)

   - **Scan #2:** 70degree, 10MHz with 100mm PCS.
     As shown in the Picture (l), Hole 1 is now invisible. The reason for that is the blind zone has increased due to increase in PCS. Other holes are now also less separate from the lateral wave as compared to the
previous scan.

Picture (l): ToFD 70deg, 10MHz, 100PCS scan

2. Effect of Frequency of sound:

- **Scan #3**: 70degree, 10MHz with 60mm PCS.

  As shown in the Picture (m) Hole 2 to Hole 4 are having good visibility due to selection of high frequency. High frequency reduces the blind zone hence increasing the detection in near surface.

  ![Picture (m)](image)

- **Scan #4**: 70degree, 2MHz with 60mm PCS.

  As shown in the Picture (n) Hole 1 is now completely merged in the lateral wave due to increase in blind zone. This is as a result of selecting low frequency of sound.

  ![Picture (n)](image)
**Conclusion:** As discussed, minor differences exist in the image pattern of different flaws and that slight difference can be used to characterize that flaw. Results can be obtained more certain without supplementing it with Conventional UT. Although use of conventional UT is better but the above discussed way of identifying flaws can be relied upon.

Another topic we discussed was about the detectability of flaws in the near surface area of the weld. After discussing, we come to our conclusion that increase in frequency of the sound reduces the area of blind zone thus increasing the detectability in even more near to surface region and vice versa. On the other hand increasing the PCS increases the area of blind zone thus reducing the detectability in near surface region and vice versa.