Case Study on Detectability of Hair line crack by

Time of Flight Diffraction technique

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Abstract

ToFD (Time of Flight Diffraction) is a much responsive and recordable technique for detecting planar defects of weld as compared to Radiography. To prove this point, a mockup of High Alloy Steel welding was prepared having 100 mm thickness to check detectability of hair cracks by both techniques. It was done by modified Welding parameters in such a way that during welding it becomes susceptible to produce small hair cracks inside it.

The experiment’s sole purpose is to check and verify the detection ability of ToFD method. All the indications found by ToFD has been cross verified by Magnetic particle Testing.

Conclusion of this paper enables the user to select the NDE method for detecting hair line cracks in High Alloy Steel. This paper reports the work carried out for preparing the test piece & the technical details to perform ToFD and Radiography. The scan plan of ToFD and details of Magnetic particle testing which reveals the flaws are also discussed in this paper.

Keywords: ToFD, Radiography, Crack, Magnetic particle Testing
**Introduction:**

ToFD (Time of Flight Diffraction) originated from tip diffraction techniques which were first published by Silk and Liddington in 1975 which paved the way for ToFD. Later works on this technique are given in a number of sources which include Harumi et al. (1989), Avioli et al. (1991), and Bray and Stanley (1997).

Bray and Stanley (1997) summarized ToFD as tip-diffraction techniques which utilized the principle that the tips of a crack when struck by a wave will diffract the signals back to the other location on the surface. The depth of these tips can be determined from the diffracted energy.

ToFD was invented in the UK in the 1970s initially as a research tool. The use of ToFD enabled crack sizes to be measured more accurately, so that expensive components could be kept in operation as long as possible with minimal risk of failure.

**Case Study:**

For this study a pipe of High Alloy Steel having 23 inch O.D. and thickness 100mm was selected. A circumferential groove was made in that pipe which had depth of 30mm and width of 30mm as shown in the picture (a). Now this groove was required to be filled by Shielded Metal Arc Welding (SMAW).

Although the regular welding procedure would have not produced hair line cracks, but a team of Welding Engineers modified that procedure in such a way that it could produce small hair line cracks during welding. Now the groove was fully filled by that process.

The next step was to perform ToFD with following parameters:

1. Wedge angle: 70degree
2. Centre Frequency: 5Mhz
3. Probe centre separation(PCS): 75mm
4. Probe element size: 6mm
5. Reference dB: 44
The picture (b) below shows the scanned image of ToFD:

Small indications are visible below the lateral wave in picture (b). It was confirmed by ToFD that those small indications were at a depth of 10-11mm from the surface.

Now the joint was radiographed. It was unable to find the indications in it.

RT was performed with following parameters:

- Radiation Source: Co-60
- Film used: D4
- Technique: Single wall Single image
- Source to object distance: 384.2mm
- Source side object to film distance: 100mm

To confirm the characteristic of the indications found in ToFD, it was decided to perform Magnetic Particle testing. As the indications found in ToFD were at greater depths inside the weld, so stepwise machining (Turning) on outer diameter of pipe was performed to reveal the indications in MT. The consequences of machining are mentioned in Table (a).
These indications were at the same location as depicted in ToFD. The size of these cracks was also same as measured. The picture (c) shows the cracks appeared on the surface in MT.

The parameters used to perform MT were as below:

- Type: Wet Fluorescent
- Magnetizing technique: Longitudinal
- Magnetizing current: ½ wave DC
- Leg spacing: 4”
- UV light level: 1100 Wb/cm²
- Surrounding light level: 15 Lux

The pipe & groove details before and after machining is mentioned in picture (d).

<table>
<thead>
<tr>
<th>Depth of machining</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>3mm</td>
<td>No indications found</td>
</tr>
<tr>
<td>5.5mm</td>
<td>No indications found</td>
</tr>
<tr>
<td>8mm</td>
<td>No indication found</td>
</tr>
<tr>
<td>9mm</td>
<td>Small hairline cracks found</td>
</tr>
</tbody>
</table>

Table (a)

Conclusion:
This study shows that ToFD is a technique to be relied upon for detecting hair line cracks as small as 2mm in length. The reason of this much amount of high sensitivity in the Time of Flight Diffraction technique is hidden in its principle of operation. Unlike conventional Ultrasonic testing the image which ToFD shows on the screen is of the diffracted as well as reflected sound from the flaw. We are unsure about the reflected sound waves being detected by the transducer because of its directional properties. But this is not the case with Diffracted sound waves. The principle of diffraction is that if a sound wave travels in a material and is confronted by a discontinuity or flaw, the tips of that flaw will produce a diffracted sound which is omnidirectional in nature. No matter this tip is how much small and sharp, it will diffract the signal and surely it will be detected.

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