Case studies on uncertainties of ultrasonic weld testing interpretation

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Abstract

Interpretation of manual ultrasonic testing of welds require greater operator skill and knowledge of the weld configuration. While performing manual ultrasonic testing, it was reported various non relevant indications as discontinues indications and vice-versa. This paper aims to discuss some of the cases where such doubtful interpretation were investigated and concluded with right results. The following are the cases will be discussed through this case study.

- Spurious Indications due to Geometry - Double-V Groove Weld
- Detection of toe-cracks by Ultrasonic testing
- Lack of fusion in a square butt weld

1. Spurious Indication due to joint geometry (Double-V Groove Butt Weld)

Near surface defects suspected as Lack of fusion (over 60 meters from the total length of 200 meters) was reported by Level-2 technicians. It was welded using SAW Process (Auto weld) and possibilities of getting large repairs of this scale are quiet common. The depth of the defect was about 3 mm from the opposite side. Since the reported depth was near surface and normal manual UT is not much reliable for the near surface defects, it was decided to study the indications to confirm whether the indications are due to discontinuities or non-relevant indications.

Careful study of these indications by the combination of excavation, Spot Radiography and re-testing after flushing the cap revealed that indeed those indications were non-relevant.

All near surface indications were plotted from one side. It appeared as LOF near the opposite surface at a depth of 3mm (fig.1). Since it is coming from the near surface there was a possibility of spurious indications coming from the weld cap due to beam spread of Ultrasound wave.

Figure-1 Cap profile has drawn using lead wire and profile gauge & the indication on CRT.

Following steps were taken to confirm the validity of UT indications:
Two locations of length 250mm each was tested after flushing the weld cap and found acceptable. No indications were noticed after flushing the cap. Refer fig.2

![Figure-2 CRT display after flush cap](image1)

250mm weld length was excavated at two locations by grinding incrementally and then tested with MT and PT. No Lack of Fusion was found.

![Figure-3 Photo showing Penetrant Testing after Excavation](image2)

*Two radiographs shoot at the suspected locations and found acceptable.

![Figure-4 Radiographic test result](image3)

![Figure-5 Reflection from Beam spread](image4)
These analyses conclude that all the near surface indications were produced by the convex profile of the weld cap. The indication received was actually resulted from the collective energy reflected from beam spread which is schematically shown in figure-5. Hence were accepted by Ultrasonic Testing.

2. Detection of Toe-cracks by Ultrasonic testing

In a routine cross-check on Full Penetration T joints some unusual indications were observed at the depth of 3 to 7mm (from scanning side) and defect location was near the weld toe area which indicates something unusual because this area is relatively easy to weld compared to middle thickness of the weld.

The indication was observed when testing with 70° - 4MHz miniature probe that grow in amplitude while moving the probe forward (figure-6). It peaked when tilting the probe away from the weld axis which is a characteristic of crack. Due to these it was suspected as toe-crack. Usually toe-cracks are tested with 45° shear wave Probe from the opposite side. The problem with 45° probe is its acute angle which produces sharp echo form the weld undercut. It is very hard to differentiate between weld undercut and near surface toe cracks.

It was decided to evaluate these indications with lower frequency probe. Factors encouraged us to test these indications with 2MHz 70° miniature probe are:

- 70° shear wave probe produces significant amount of surface waves compared to other angle probes.
- Lower frequency probes produces greater amount of surface waves compared to its higher frequency counter part.
- More over the lower frequency increases the reflectivity of the defect.

![Figure-6](image)

The defect was evaluated with 2MHz 70° probe. A sharp indication with amplitude greater than 250% of the DAC (thick line in figure-7) was found. It means it is a planar defect and most probably a crack. The indication location was ground and tested by Magnetic Particle Testing which revealed intermittent surface cracks (figure-8).
After confirmation, scanning technique was revised (figure-9 Note-1). All similar joints welded using the same material, thickness and same welding process were tested with 2MHz 70° Probes and found many toe cracks running into several meters (figure-10). Scanning was extended to all accessible surfaces (figure-9) and cracks were found on all toe areas (branch member side toe and main member side toe).

**Note-1:**
Scanning Detail:
1. 0° scanning from branch member side.
2. 60°, 70° (minimum) Angle beam scanning from face 1 and 2.
3. 70° - 2MHz probe scanning from face 1, 2, 3, 3A.
4. 0° scanning where accessible from face-4.
It was demonstrated that the 2MHz 70° probe is very useful to find out near surface cracks which is very hard to detect by other probes. It gives high confidence level. The depth of defect was over estimated when plotting (or calculating) because 70° angle was used for this. In order to reduce this, the equipment was calibrated using the V1 block’s 4mm notch and the angle adjusted (in USM35) until it give 4mm depth. Then the same angle was used while testing to get accurate depth info. Following pictures gives various crack indications recorded using 2MHz probe.

Figure 9A: Ultrasonic screen display for various crack indications

Figure-10 Crack Identified by 2MHz 70° Probe and its extent

Figure -11 Distributions of cracks over the whole joints
Later it was used to establish the depth of transverse cracks found by MPI (figure-11). The multiple echoes indicates that the crack probably have a branch which extends much deeper than the first.

![Figure-11, MPI Indication of the toe cracks](image)

It was also used to test nozzle welds (figure-12) for cracks. Scanning was performed from the pipe. This probe proved its ability to detect the near surface cracks that are usually missed by other probes.

![Figure-12 – Crack Indication in DSS Pipe Nozzle weld](image)

### 3. Lack of fusion in Square butt weld

While testing square groove butt welds, an indication was observed with the amplitude of 25% to 40% of DAC. At few locations it touched 50% line but the length remains with in acceptable level. The indication was intermittent and various lengths. Accumulated length of this indication was over 20 meters which accounts about 75% of total weld length. According to NDT guide from classification body, the indication was acceptable. The schematic location of the discontinuity is shown in figure-13A.

![Pulse-Echo](image)
The location of the defect was at the centre of the weld. Therefore, based on the joint configuration it was suspected that it could be more serious (LOF/LOP) than the evaluation based on the screen amplitude. The reason behind the suspicion was the sound beam’s reflectivity. Due to square butt configuration, the reflectivity of the ultrasonic beam should be poor compared to Single – V and Double – V bevels. Tandem technique is more suitable to determine the severity and extent of these indications.

The weld was re-tested using tandem technique. The amplitude of the same indication in tandem technique was about 180% of reference. In other words it was 5 to 8 times greater than the indications observed in regular pulse-echo mode. Finally the weld was rejected based on tandem amplitude. Indications from both techniques are given in figure-15.

The tandem technique is schematically shown below in figure-13B. It uses two probes – one as transmitter and other as receiver. Probes are positioned to receive maximum energy in this technique. The probe locations were pre calculated based on expected defect depth. The same reference hole used for pulse-echo (figure-14) was picked up and kept at 80% of FSH using tandem technique then used to evaluate the discontinuity.

Rejected weld was inspected visually after gouging and Lack of Fusion was found almost entire length of all welds (figure-16).
Tandem Technique Indication -Location-1 (Indication stored 5dB less than reference (Ref. = 65 dB))

Tandem Technique Indication -Location-2 (Indication stored 5dB less than reference (Ref. = 65 dB))

Figure-15 Square Butt Indications with Pulse Echo and Tandem Technique

Figure-16 Lack of fusion detected by tandem technique

Conclusion:
- These examples vindicate the requirement of highly skilled operator.
- Good experience and analytical skill are essential for an ultrasonic test operator.
- Near surface indications requires further evaluation to confirm its validity.
- Technician must know the joint configuration in order to establish suitable technique as and when required. Technician should report to his Level-III when ever he encounters unfamiliar/uncommon indications so that the Level-III can evaluate it further and advise the technician.
- Test with 70° - 2MHz probe when ever near surface indications are observed by 70° - 4MHz probe.
- An operator should not miss any detrimental defect and at the same time he should not give unwanted repairs.

Key words
Non relevant indications, weld near surface defects, toe cracks, square butt weld, uncertainties,

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