NDT of Rail Welds during the Construction of the Rapid Transportation System in Kaohsiung

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Abstract. A railway line consists of a large number or string of individual rails welded together. Today there exist two kinds of method for welding the rails. For both methods it is of paramount importance to assure the quality of the weld in order to meet technical requirements, specifications and ensure safety.
Non-destructive technologies, such as UT for the inspection of internal or inside flaws and MT/VT for surface flaws have been in practical use for the inspection of many thousands of rail welds.
The paper will report on collecting these results and analyzing them, utilizing the information as feedback regarding the welding process and correcting any potential problems.
The results of this work show many advantages. Flaws are detected reliably and accurately and can be repaired early. This approach helps to decrease quality-related costs and assures the weldment quality and thus safety to humans and the environment.

1. Introduction

The total combined length of the Red and Orange Lines of the Kaohsiung Rapid Transit System (KRTS) are 42.7 kilometers with 38 stations. The track requirements at KRTS are based on practices in mass rapid transit (MRT) systems around the world. Rails on all tracks are UIC60 rail section. Track follows a nominal gauge of 1435mm with construction tolerance of plus or minus 1.5mm for all tracks. The design speed for the main line is 90 km/hr, although the maximum operating speed will be 80 km/hr. In depots, the design speed will be reduced to 35 km/hr and the operating speed will be 25km/hr.
Flash-butt and thermite welding make the system-wide continuous welding rail (CWR) possible and enhance track performance. Fish-plated rail joints are seldom used with the exception of the insulated rail joints (IRJ) for signaling/power and track interface.
After the civil construction is complete, the track work contractor shall provide temporary transport routes for E/M facility contractors, including rolling stock, signalling, power supply etc., so they can do their site work separately. An access dates and routes are always critical paths during MRT construction.

2. Inspection Requirements

2.1 Surface Quality

All rail welds shall be inspected by Magnetic Particle Testing which using the Yoke Technique with Wet particles.

2.1.1 Testing Procedure

(1). All welds shall be ground to final profile prior to undertaking this procedure.
(2). Cleaning shall be accomplished by detergents, organic solvents, descaling solutions, paint removers and vapour degreasing.
(3). Prior to magnetic particle examination, the surface to be examined and any adjacent area within at least 25mm of the surface to be examined, shall be dry and free of any dirt, grease, lint, scale, welding flux, spatter, oil or other extraneous matter that would interfere with the examination.
(4). Examination shall be done by the continuous method. i.e. the magnetizing current remains on the parts to be examined while the examination medium (ferromagnetic particles) is being applied and while excess examination medium is being removed.
(5). Alternating current electromagnetic yokes shall be used and have a lifting power of at least 4.5 kg at the maximum pole spacing. At least two separate examinations shall be carried out on each area; in the second examination the lines of magnetic flux shall be approximately perpendicular to those used for the first examination in that area.
(6). To verify the adequacy and direction of the magnetizing force the “Magnetic Particle Field Indicator” shall be used by positioning the indicator on the surface to be examined. When a clearly defined line of particles is not formed or not formed in the desired direction, the magnetizing technique shall be adjusted accordingly.

2.1.2 Acceptance Standards

All surfaces examined shall be free of:
(1). Relevant linear indications.
(2). Relevant rounded indications greater than 3mm.
(3). four or more relevant rounded indications in a line separated by 1mm or less edge to edge.
All indications/discontinuities are unacceptable and shall be removed.

2.2 Internal Quality

All rail welds shall be ultrasonically tested in the track. The rail either side of the weld shall be initially scanned for horizontal defects, and subsequently three tests shall be applied to both fusion faces of the weld. These scans shall detect vertically oriented lack of fusion defects in the head, web and foot areas of the welded joint.

2.2.1 Initial Rail Scan (0°)

(1). Prior to the application of any scan to the fusion faces of the weld 500mm of the rail on either side of the joint shall be scanned for horizontal defects using the0° probe. At the same time the rail depth either side of the weld shall be measured and recorded.
(2). The timescale shall be calibrated for 200mm full scale, using the 100mm dimension of the STB-A1 calibration block and the 0° probe.

2.2.2 Tandem Probe Scan Procedure

(1). The tandem probe scan shall be applied to detect lack of fusion defects on the vertical fusion faces in the head and web of the welded joint. The area covered by this scan is shown schematically in Figure 1.

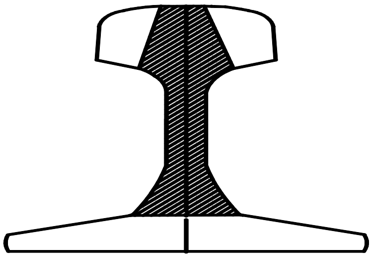

FIG.1- Area covered by Tandem Probe Scan for Rail Head and Web

(2). Using one of the 45° probe from the tandem probe rig, and the 100mm quadrant of the STB-A1 calibration block, the timescale shall be calibrated for 250mm full scale. The other 45° probe shall then be connected to the instrument and the switch made to double probe working.

(3). Attach the probes such that the probe connected to the TX socket is nearest the datum's line and is looking away from the weld. The second probe connected to the RX socket shall be looking towards the weld. This arrangement is illustrated in Figure 2.

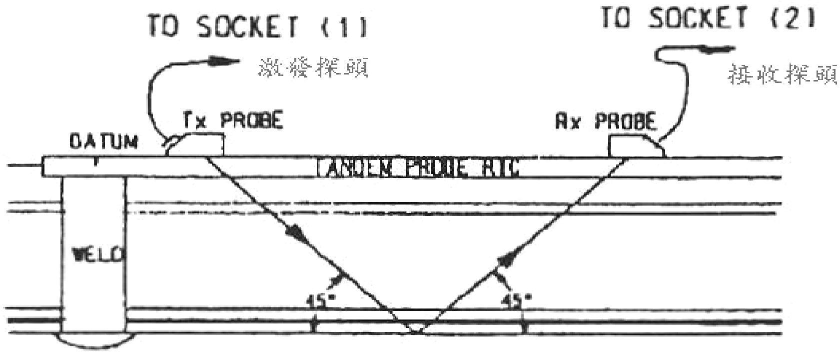

FIG.2- Tandem Probe Rig Scan Arrangement for Setting Test Sensitivity

(4). By movement of the probes along the probe guide maximise the signal from rail bottom. Using the attenuation control set this signal to full screen height and adds 10dB.

(5). Remove the TX probe from its carriage and replace it such that the probe looks towards the weld. After ensuring that adequate couplant has been applied move the probes backwards and forwards along the probe guide.

(6). Signals from any lack of fusion defect present should appear at approximately the same range as the signal used to set the sensitivity see Figure 3. This scan shall be applied twice once from each side of the weld.

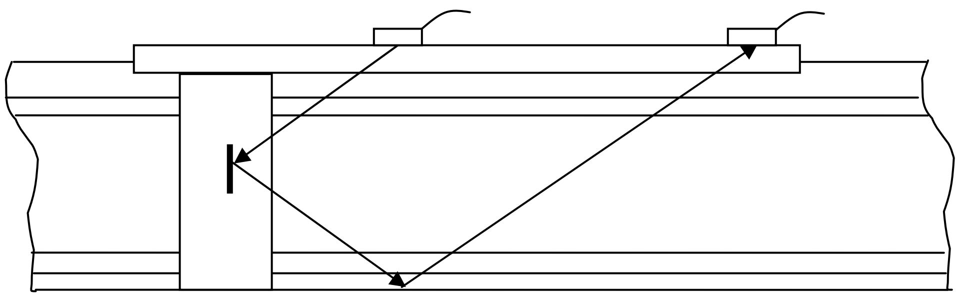

FIG.3- Tandem Probe Rig Scan Arrangement for Vertical Defect Scanning

(7). If a defect signal is found the operator shall record its amplitude and the stand-off distance of the TX probe measured from the datum’s line on the probe rig. If the defect signal reaches amplitude of ½ screen height the weld will be rejected and shall be removed from the track.

2.2.3 Scanning of Lower Web and Foot from Rail Head

(1). This scan is required to inspect fusion face of the weld in the lower web/foot of the rail for lack of fusion defects extending to the rail bottom. The area covered by scan is shown schematically in Figure 4.

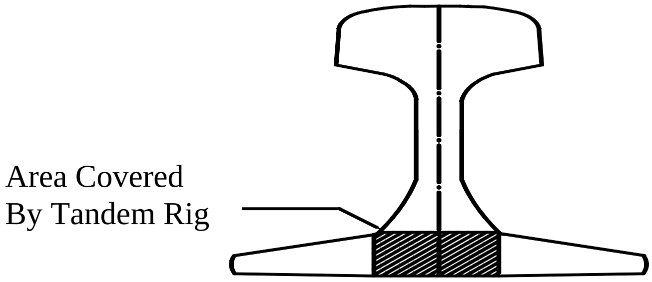

FIG.4- Area Covered by Scan Single 45° Probe for Rail Lower Web and Foot

(2). Timescale calibration shall be carried out as stipulated above. Following this remove both probes from their carriages disconnect the RX probe from the instrument and switch to single crystal working. The test sensitivity specified for the tandem rig scans shall be maintained during this test.

(3). To scan the lower fusion face place the probe on the rail head such that the stand-off distance from the centre-line of the weld to the probe index is approximately equal to rail depth. i.e. about 172mm for UIC60 section rail. Scan the lower fusion face by moving the probe about 40mm either side of this position see Figure 5.

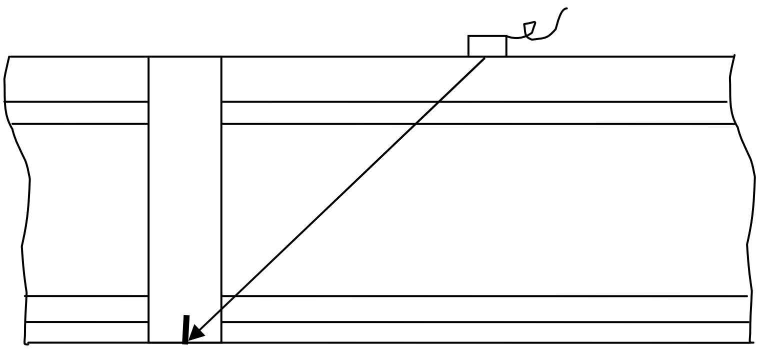

FIG.5- Single 45° Probe for Lower Web and Foot Scanning

(4). Signals from lack of fusion defects should appear at a range approximately equal to the slant range of the rail section being tested (for UIC 60 the range is 243mm). This scan shall be applied twice once from each side of the weld.

(5). If a defect signal is found the operator shall record the amplitude and probe stand-off distance from the weld centre-line. If the defect signal reaches ½ screen height the weld will be rejected and shall be removed from the track.

2.2.4 Scanning of Rail Foot

(1). This scan is required to inspect the fusion faces in the rail foot. (Outside of the central area) for lack of fusion defects. Figure 6 illustrates schematically the area covered by this scan.

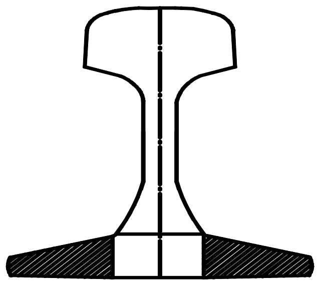

FIG.6- Area Covered by Single 70° Probe for Rail Foot Scanning

(2). Timescale calibration shall be carried out by using the 5 MHz single crystal 70° probe and calibrated for 200mm full scale. The use of a 0-6 divisional screen will make this calibration easier to carry out.

(3). Place the probe on the side of the calibration block (20mm Thickness) and obtain the ½ skip signal from the edge of the block. This signal should maximise at a range of about 55mm(0.5 Skip) at the division on the time scale, see Figure 7. Once maximised, the attenuator shall be used to set this signal to full screen height and add 10 dB.

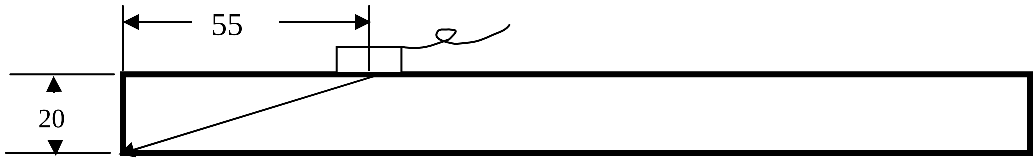

FIG.7- Single 70° Probe Setting Test Sensitivity for Rail Foot Scanning

(4). Place the probe on the outer flat portion (toe) of the rail foot such that the probe index is about 40mm from the weld reinforcement. This area of the fusion face shall then be scanned by moving the probe laterally and transversely with respect to the weld, see Figure 8. The transverse movement must be at least 40mm either side of the position described above. In order to detect lack of fusion defects in the extreme edge of the foot rotational movement of the probe shall also be conducted.

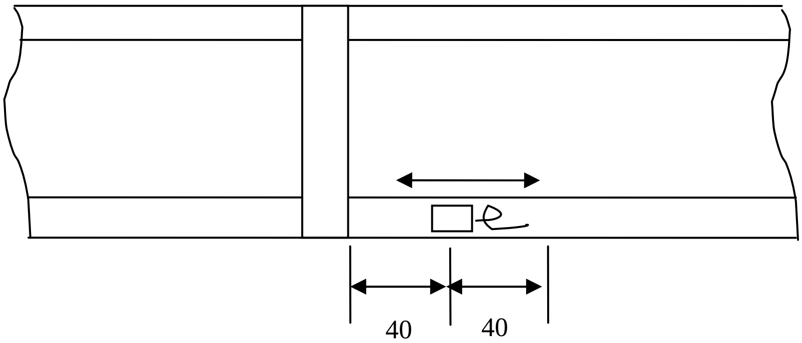

FIG.8- Single 70° Probe Movement for Rail Foot Toe Scanning

(5). Having scanned from the outer flat portion of the rail foot the probe shall be placed on the sloping protion of the rail foot (ankle) such that the probe index is 75mm from the weld reinforcement. This area may then be scanned in the manner described in item (4) above except that the transverse movement should be 75mm to either side of the position described therein see Figure 9. Rotational movement of the probe shall also be necessary in order to detect lack of fusion defects in the extreme edge of the rail foot in this area.

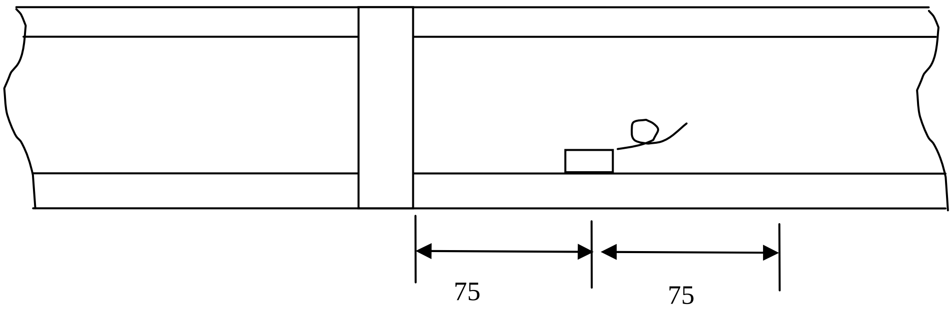

FIG.9- Single 70° Probe Location for Rail Ankle Scanning

(6). The scanning of fusion faces shall be applied four times on each weld as shown in Figure 10.

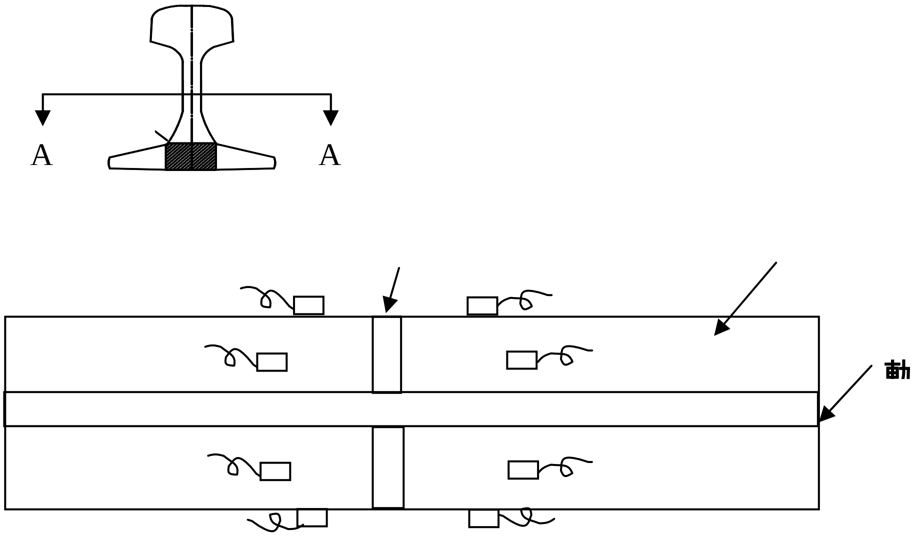

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FIG.10- Single 70° Probe Location for Rail Foot Scanning

(7). If a defect signal is found the operator shall record its amplitude and the probe stand-off position from the edge of the weld reinforcement. If a defect signal reaches 1/3 screen height the weld will be rejected and shall be removed from the track.

3. Inspection Result (Up to the April)

LINE	Weld Method	Done With	RJ-UT	RJ-MT
RED	Flash-butt	5471	0	9
	Thermite	845	95	29
ORANGE	Flash-butt	1100	1	1
	Thermite	0	0	0

4. Conclusions

The truly Non-destructive Testing execution will guarantee the welding equipments or machines to operate smoothly and enhance the production efficiency. As previously stated, MT/UT inspection can yield a confidence level of approximately 95%.
The range of NDT includes quality inspection and processing measuring. The items of quality inspection are:
(1). To detect surface/internal defects;
(2). To measure dimension;
(3). To measure the parameter of processing factors;
The purpose of processing measuring is to get the information quickly for the feedback to reach and monitor the optimum processing control for welds quality.
Under the dual requests of the weld output and quality, the time of machinery maintenance has been limited; therefore the machinery reliability, availability, maintenance, and safety will grow more important day by day. The technology of welding has trended from the waste energy, air pollution to computer-based, optical-electric, energy improvement and hi-tec related business as well.

References

[1] Magnetic Particle Testing Procedure of Kaohsiung Rapid Transit System
[2] Ultrasonic Testing Procedure of Kaohsiung Rapid Transit System
[3] DRAFT of prEN 13674-1