Jurnal
Teknologi

Full Paper

EVALUATION OF RAIL HEAD SURFACE REPAIR USING SMAW PROCESS WITH PRE HEATING CONDITION

Article history
Received
31 January 2015
Received in revised form
30 April 2015
Accepted
31 May 2015

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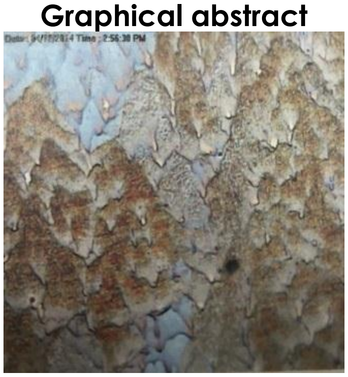
Graphical abstract



Abstract

The Railway maintenance industry has been using a welding process to repair the damage on the rail head surface due to its constant and continuous friction with train wheels. The damage area always reoccurs at the same location. A preheating condition has been set in this study to evaluate if it's an improvement to the rail head surface. As preheating is a process that slow's the cooling rate of the weld and the base material, resulting in softer weld metal and heat affected zone microstructures with a greater resistance to fabrication hydrogen cracking. The Spectrometer and Hardness test are applied in order to study driven changes in the microstructure and macrostructure of rail specimens at the rail head surface. It is shown that welded layers are clear from any defect due to the normal pressure with rapid change of temperature during usage and also surface oxidation. Welded layer were free from any visible defect such as porosity and crack.

Keywords: Rail; SMAW; spectrometer test; rail head surface; microstructure; macrostructure

1.0 INTRODUCTION

The usage of trains as a mean of transport is becoming more popular due to the development of high-speed trains. This requires high quality material for rail tracks to decrease the potential of structural deformation. The surrounding atmosphere, contact temperatures, which can reach several hundred °C due to slipping and friction between wheel and rail and their rapid changes in wheel/rail operating conditions may cause severe thermal stresses [1-4]. Moreover, the contact pressure, which can exceed 1GPa, and surface shear stresses up to several hundreds of MPa cause severe plastic deformations [5]. Consequently, the modifications of the rail surface structure and phase composition lead to surface corrugations and formation of micro and macrocracks [6].

It is common in the railway track maintenance industry to use the welding process to repair the rail head surface. The most frequently used welding types in a railway maintenance activity are electric welding due to its portability. All of the electric welding, such as shielded metal arc welding (SMAW), gas metal arc welding (GMAW) and flux-cored arc welding are used to prolong the service of running rails due to low cost, more efficient and faster maintenance repair time [7-8]. Welding process also allows some damaged rails that did not require immediate replacement to be repaired on site in the damaged area. The surface structure at the rail head surface receive the maximum amount of wear and damage due to its direct contact with the train wheel absorbing the continuous friction and changes in temperature. However, rail wear and damage always repeat at the similar spots [9].

Wear of rail surface, usually occurs soon after the track has been put into service. This wear mainly caused by the wheel and rail contact during braking or accelerating force movement. Without any proper repairing activity, it will affect the riding comfort and safety, creation of noise due to the effect of corrugated surface, there can be inconsistencies train movement due to waving track and train delay caused by the procedure at go slow zone and reduces trains frequent. Some case of vibration may contribute serious rail damage that affects others track and train components. Track component replacement job, especially the running rail requires costly skilled manpower and special machineries [9]. As an alternative, build- up welding can be performed in order to restore worn out and damaged rail. Nevertheless damaged rail always repeat at the previous welded area. It may be caused by improper use of consumable during the repairing process. This study was conducted in order to evaluate the quality of welding repair on running rail RE115 using Magna 488-Rail consumable welding rods currently used at Track Network Maintenance Department of RapidKL Kelana Jaya Line. Figure 1(a), Figure 1(b) and Figure 1(c) shows common running rail damage that occurs at RapidKL Kelana Jaya Line.

Figure 1(a) Wheel burn

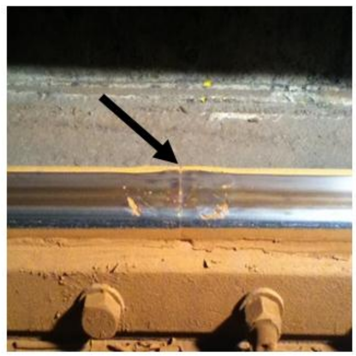


Figure 1(b) Embedded rail

Figure 1(c) Surface crack

2.0 EXPERIMENTAL

2.1 Material

Running rail samples for this study were obtained from Track Network Maintenance Department of RapidKL Kelana Jaya Line, in order to evaluate the quality of welding repair on running rail RE115 using Magna 488-Rail consumable welding rods (Figure 2). Running rails are made from very high quality steel alloy and subject to very high stresses. In order to have the required qualities of strength, wear and corrosion resistance and fatigue endurance, running rails was specifically rolled.

Running rail is graded by weight over a standard length. For example, RE115 running rail is graded in pound per yard that is 115 pounds per yard (lbs/yd). The Nominal Composition Limited for rail RE115 is shown in Table 1. A heavier running rail can resist higher train speeds and greater axle loads without sustaining damage compare to lighter running rail. The samples of the running rail were prepared before welding repair process consists of grinding and surface cleaning. Hand grinders were used to grind out all the damage on the rail head surface before the experiment began. During this process, any surface defects shall be grinding out completely as confirmed by visual inspection.

In order to avoid overheating during the grinding process, light grinding pressure is applied. All surfaces within 50mm of the welding area must be free of scale, oil, grease, paint and other foreign materials.

Figure 2 RE115 Rail sample

Table 1 Nominal Composition Limited for rail RE115

Manganese	0.80-1.10
Carbon	0.72-0.82
Sulphur (max)	0.030
Phosphorus (max)	0.030
Silicon	0.10-0.60
Chromium	0.25-0.40
Hydrogen ppm	3 max

2.2 Preheat

As an addition to the normal rail head surface repair work, this study would like to evaluate if a preheated condition were applied before the welding process occurs will produce a better hardness value. The immediate joint areas were preheated to a temperature condition of 370°C, as determined by an Infrared Thermometer. This 370°C temperature must be maintained during the welding process. If for any reason, the progression of a weld is delayed or interrupted, it must not be resumed until the temperature has been again regulated to 370°C.

2.3 Welding

The welding processes were conducted by a qualified welder from RapidKL. During the welding process, all surfaces within 50mm of the weld area must be free of scale, oil, grease, paint and other foreign material. Welding process was completed by using ORIGO™ EDW 610D SMAW welding machine. This machine was manufactured by ESAB Sweden.

As of the sample preparation, the welded running rail was cut into 3 samples of 10 cm in length. Since the running rail was a hard material a band saw cutting machine is used for this cutting process. Next the samples were cut into small cube samples of 15mm using abrasive cutting machine.

3.0 RESULTS AND DISCUSSION

3.1 Spectrometer Test.

The test result shown in Table 2 shows that nominal material composition of Magna 488-Rail filler metal has Chromium and Nickel at 3.0% and 2.85%, respectively, and high Manganese contain 13.65%, it is a type of alloyed austenitic stainless steel with Moly-manganese. Meanwhile the material composition of the base metal is high carbon steel alloyed with Silicon, Manganese and 0.23% of Chromium.

Table 2 Spectrometer Test Result

Material	Material Composition	
	Base Metal (%)	Magna 488-Rail (%)
C	0.82	0.69
Si	0.438	0.383
Mn	1.12	13.65
P	0.0015	0.0046
S	0.0044	<0.001
Cr	0.230	3.0
Ni	0.090	2.85
Mo	0.0027	0.088
Al	0.0047	0.0056
Cu	0.0073	0.004
Co	0.0060	0.019
Nb	<0.0040	0.019
V	<0.0010	0.052
W	<0.0010	0.028
Pb	<0.0030	0.054
Mg	<0.0010	0.0053
B	<0.0005	0.0017
Sn	0.0014	0.014
Zn	<0.0020	<0.002
As	0.0028	0.0051
Bi	<0.0020	<0.002
Ca	0.0013	0.0007
Ce	<0.0030	0.015
Zr	<0.0015	0.015
La	<0.0010	<0.001
Fe	97.3	79.1

3.2 Hardness Test Result.

The Vickers Hardness test result value can be viewed in Table 3, it shows that average hardness of weld metal is 323.32 HV meanwhile average hardness of base metal is 377.22 HV. Hardness of the welded area in the heat affected zone (HAZ) is 419.82HV higher than the hardness of base metal and weld material, despite the base material was preheated. Had there been no preheating, it would have been higher due to the formation of martensitic structure, a common property of manganese steel. The weld material value is slightly lower than the base metal because preheating has no influence on the hardness of the weld deposit.

Table 3 Hardness Test Results.

Testing Area	Hardness (HV)		
	Sample 1	Sample 2	Average
Weld Metal	361.2	288.5	323.32
	361.0	297.7	
	325.6	305.9	
HAZ	421.6	406.6	419.82
	458.0	407.8	
	418.0	406.9	
Base Metal	366.9	417.8	377.22
	349.7	413.0	
	327.8	388.1	

3.3 Macrostructure and Microstructure Observation.

Figure 3(a), shows the optical macrostructure of RE115 rail welded with Magna 488-Rail. The result shows that the welded layer is clear from any defect such as porosity and crack. The fusion area between base metal and filler metal is good, with absence of inter-metallic [10-11].

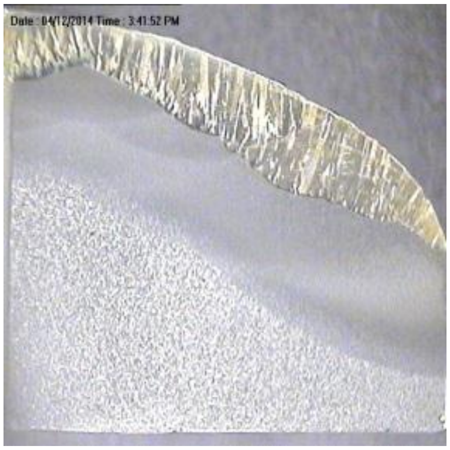


Figure 3 (a) Macrostructure of RE115 Rail Welded with Magna 488-Rail

Figure 3 (b) shows the microstructure of base metal which is RE115 rail consist of pearlitic microstructure. Since pearlite consists of soft ferrite and hard cementite, therefore RE115 rail, presumably achieves a high resistance to wear because of hard cementite. Lamellar structure also appeared in Figure 3(b) it explains the high value of hardness property of the rail [12].

Figure 3 (b) Optical Microstructure of Rail Base Metal (500x)

Figure 3 (c) shows the microstructure of heat affected zone (HAZ) area. Microstructure of HAZ area also has pearlitic structure but with finer grain as compared to the base metal. This result occurred due to the thermo mechanical treatment of HAZ area during the welding process.

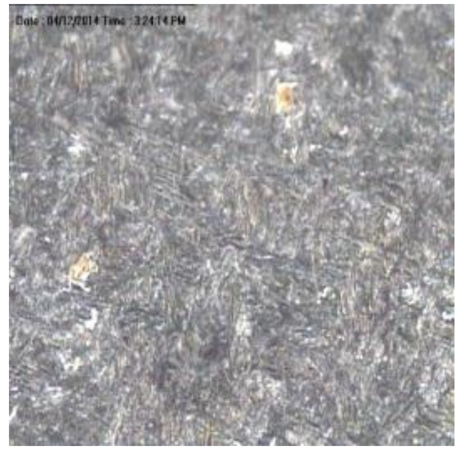


Figure 3 (c) Optical Microstructure of HAZ (500x)

Figure 3 (d) indicates that the welded layer consists of delta ferrite microstructures. This delta ferrite microstructure may occur from slow cooling rate after the welding process has completed in effect, of the preheating process and also the post heat weld process after the rail is cooled using room temperature [12].

Figure 3 (d) Microstructure of welded layer

4.0 CONCLUSION

As a result, from the optical macrostructure and microstructure, it shows that the welded layers are clear from any surface defect. The hardness test indicates that the average hardness at welded layer is slightly lower than the hardness of the base metal, welding is easier to perform without surface cracking. Preheating has no influence on the weld deposit, but help to prevent the formation of martensite crack at the heat affected zone. The potential of repeating rail damages can still occur, however this welding repair is still the best method for maintenance activity of running rail because it can extend the service life.

Acknowledgement

The authors would like to thank the Research Management Institute (RMI) of Universiti Teknologi MARA (UiTM) and Ministry of Education, Malaysia for financial support and facilitating this project support to this study through Research Acculturation Grant Scheme (RAGS) awards 600-RMI/RAGS 5/3 (47/2013).

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