Comparative Study of H350R and E8016 Electrode in Surface Hard-Facing Welding of 100 pound/yard Railway by Shielded Metal Arc Welding

การศึกษาเปรียบเทียบชนิดของลวดเชื่อม H 350R และ E 8016 จากการเชื่อมพอกผิวแข็งรางรถไฟขนาด 100 ปอนด์/หลา โดยกระบวนการเชื่อมอาร์คโลหะด้วยลวดเชื่อมหุ้มฟลักซ์

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Received: May. 2, 2019 **Revised:** Aug. 26, 2019 **Accepted:** Dec. 17, 2019

Abstract

This research was a comparative study of H350R and E8016 electrodes in surface hardfacing welding of 100 pound/yard railway made from shielded metal arc welding. The penetrant testing to examine the surface found a 5 - 8 millimeter crack from welding with electrode H350R, but no crack or porosity from welding with electrode E8016. From the macrostructure examination, there was no recognizable crack or porosity. The microstructure examination showed that welding with both electrodes produced pearlite structures. The crack width from welding with electrode H350R was around 500 - 1,200 microns. However, microstructure testing of the heat-affected zone showed that there was no crack from welding with either electrode. The microstructure consisted of ferrite mixed with a martensite structure evenly dispersed. However, in the welding with electrode H350R, the martensite structure was smoother than in the welding with E8016. This was because E8016 contained a large amount of silicon and manganese giving it a rougher grain, directly affecting friction resistance, tensile strength and vibration. It can be concluded from the study, therefore, that the H350R welding electrode is not suitable for 100 pound/ yard railway surface hardfacing welding.

Keywords: surface hardfacing welding, type of welding electrode, shielded metal arc welding

1. Introduction

Logistics management in both national and international level is currently trendy and continuously developed. Due to the analysis, choosing appropriated transportation for products and business need is a way for making the most effective cost with various major systems: water, land and air transportation. However, when discussing popular logistics in the country that is able to carry a large amount of products and passengers, it is definitely a railway system. Its wide range of beneficial characteristics includes engine, containers, a lower portion, and a railway system which has to receive the weight of the train (Parighatprecha, R. Suthasupradit, S. Paoleng, P., 2014). The loss of railway's usability mostly occurred in welding line and rail's surface where wheels connected to rail's surface while moving. This research focuses to study the trail-like damaged surface which occurred from the rubbing between wheels and rail's surface.

Information from the Khon Kean Permanent Way Maintenance Division, State Railway of Thailand mentions problems of wear and tear on the surface of railway that occur from accelerated speed of train while moving from a station or up a hill that uses traction of the whole train procession. Although there is a regulation for speed acceleration while moving out of a station, it is impossible to obey since some train processions gain more weight than usual, and with that regulated speed, they are not being able to move out of the station. Consequently, speed acceleration beyond regulation is necessary and this causes wheel-spin condition while it is in motion. This problem directly affects wheel and surface (Correa, N. Vadillo, E. G. Santamaria, J. Herreros, J., 2016). After that, the Permanent Way Maintenance Division has to change the rail because it contains trails from erosion and cracks from inconsistent vibration. Accordingly, this fundamental study proposes the idea to solve this problem with railway hard-surfacing welding with Shielded Metal Arc Welding. Surface hard-facing welding is a process of filling the material from welding electrode to cover flaws on rail's surface. Meanwhile, during the welding period, there is a limitation on heating before and after welding. Heating while welding and cooling down with contraction of welding joint could cause crack after welding. The welding that the Maintenance Division of Khon Kaen Province uses is the shielded metal arc welding with H350 electrode which affects cracking after welding. Therefore, selecting appropriate welding electrode is also an important role in surfacing hard-facing welding. Because the H350R electrode has good wear resistance, and E8016 electrode has a high tensile strength, they are chosen for this research.

2. Objective

2.1 To study suitability of H350R and E8016 electrodes for surface hard-facing welding that does not produce crack

2.2 To compare results from variables of surface hard-facing welding in metallurgy structure of 100 pound/yard railway by Shielded Metal Arc Welding

3. Methods

3.1 Materials

The materials in this experiment was standard railways UIC 100A (Railway size 100 pound/yard) with chemical composition as shown in Table 1. As the steel railway has high level of carbon and manganese, it directly affects the capability of welding in relation to heating process in before-midst-after welding. Selecting a wrong welding process or inappropriate variables may produce crack in the surface of railway. Moreover, this railway steel has high tensile strength of 880 N/mm^2 with 10% Elongation and hardness of 309 HV. It is definitely significant to select the type of electrode with chemical composition as specified in Table 1 and similar mechanical properties as the railway material. Since the component of welding electrode mostly affects mechanical properties, the hardness after welding must not exceed the hardness of wheel ring of the train at 350 HV (Herbst, B. 1998) in order to protect the wheel ring from erosion while rubbing. Hence, this research prepared the experimental working piece of 200 millimeter in length.

Table 1 Chemical composition and filler metal (wt%)

Material	C	Si	Mn	P	S
UIC 100A	0.60 – 0.80	0.10 – 0.50	0.80 – 1.30	≤0.04	≤0.04
AWS E 8016	0.08	0.52	1.20	0.016	0.010
H 350R	0.14	0.45	0.54	-	-

3.2 Welding parameter

1) Shielded Metal Arc Welding.
2) Welding Wire with tensile strength AWS E8016, 4 millimeter.
3) Hard surface welding wire GEMINI grade H 350R, 4 millimeter.
4) The experiment was repeated 3 times.
5) Welder with Skill Development Standard Level 1.
6) Examine the top welding surface with penetrant testing (PT).
7) Examine the cross-section surface with penetrant testing (PT).

8) Examine the macrostructure and microstructure of welding with optical microscope (OM).

3.3 Surface hard-facing

This research used surface hard-facing welding of 100 pound/yard railway by Shielded Metal Arc Welding as shown in Figure 1 (oval) which based on arc welding between welding electrode and working material (Railway's surface). In arc welding, metal component from the electrode will be filled in the railway's surface covering 1 layer of welding line not over 80 millimeter. This is based on an examination of the impairment of surface with not over 60 millimeter length and not over 3 millimeter depth - fundamental information gained from the Khon Kean Permanent Way Maintenance Division. Flat welding (PA) by ISO standard used arc spacing of 2 millimeter, tile angle of welding electrode of 60 - 75 degree for metal filling and dispersing in the direction of welding line, welding with electric current of 130 Ampere, DCEP welding current, and invariant welding speed of 200 millimeter /minute. Warming the working piece before welding at 250 ^{o}C for 10 minute (Zerbst, U. Lund, R. Edel, K.O. Smith, R.A., 2009) with oxygen-acetylene gas (Carburizing flame) was recommended to disperse the heat in the surface area of railway. Temperature was tested with K Type Infrared Thermometer.

Figure 1 Surface hard-facing welding of 100 pound/yard railway

3.4 Preparation of test pieces after welding

The working piece preparation according to ASTM standard was examined as shown in Figure 2. The working piece A was examined by penetrant testing (PT), preparing by rubbing with sandpaper no. 150 – 1,200. Then the welding surface on top and cross section was examined. The working piece B was examined for metallurgical structure with 6 spots in weld zone (WZ) and Heat affected zone (HAZ), preparing by rubbing with sandpaper no. 150 - 1,200 and rubbing the surface with alumina oxide 1 micron. After that, abrade the surface of working piece with 2 ml Fluor-hydric acid diluted solution concentration, 5 ml of Nitric acid and 200 ml of distilled water. Then wash with alcohol and water, as well as dry blowing.

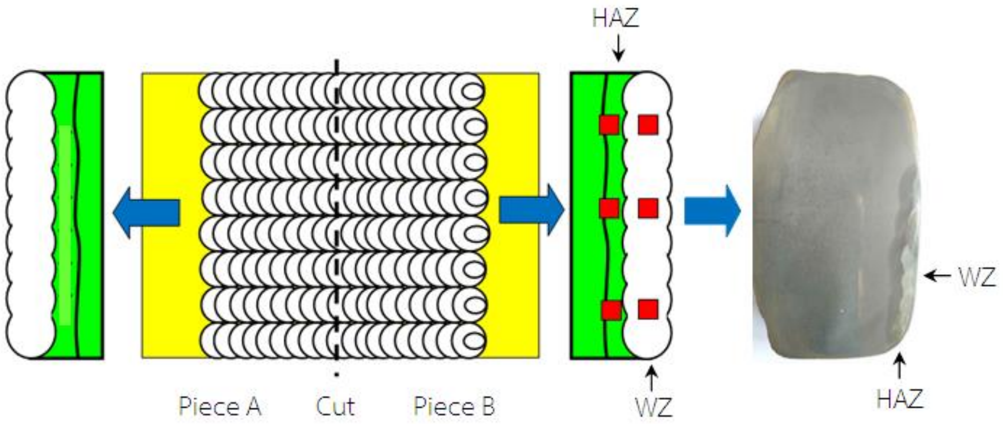

Figure 2 Preparation of test pieces after welding

4. Results

4.1 Examining surface of the top welding zone with penetrant testing found that there was 5 - 8 millimeter long crack in welding zone from welding with electrode H350R, but no crack in the welding zone from welding with electrode E8016.

4.2 Examining surface of the cross section welding zone with penetrant testing found that there was 1 - 2 millimeter long crack in welding zone from welding with electrode H350R occurred while welding. However, there was no crack or porosity in the welding zone from welding with electrode E8016.

4.3 The macrostructure examination found that there was no recognizable crack or porosity. However, in welding with electrode H350R, the heat-affected zone (HAZ) was narrower than welding with E8016 electrode. This was because the chemical property of H350R electrode has more carbon than E8016. This caused the low melting point which affected the capability of welding.

4.4 Examining the welding zone found that both electrodes consisted of Pearlite structure. From welding with electrode H350R, there was crack around 500-1,000 micron. Hence, the electrode H350R was not proper for surface hard-facing of 100 pound/yard railway. The microstructure in heat-affected zone showed no crack from welding with both electrodes. The microstructure consisted of ferrite mixed with martensite structure evenly dispersing. From welding with electrode H350R, the martensite structure was more smoothly than welding with E8016, which has much more amount of silicon and manganese and its grain was rougher than welding with H350R.

5. Conclusion and Discussion

5.1 Examine the top welding surface with penetrant testing (PT)

From examining the top welding surface with penetrant testing in welding with H350R, there was 5 - 8 millimeter long crack in welding zone as shown in Figure 3 (oval) because of residual stress from cooling after welding. This caused contraction in welding zone and became crack (Poznyakov, V.D. Kiriakov, V.M. Gajvoronsky, A.A. Klapatyuk, A.V. Shishkevich, O.S., 2010). Later, this crack affected vibration while the train was moving with fatigue and increased cracks throughout the railway. On the other hand, there was no error in welding surface while welding with electrode E8016.

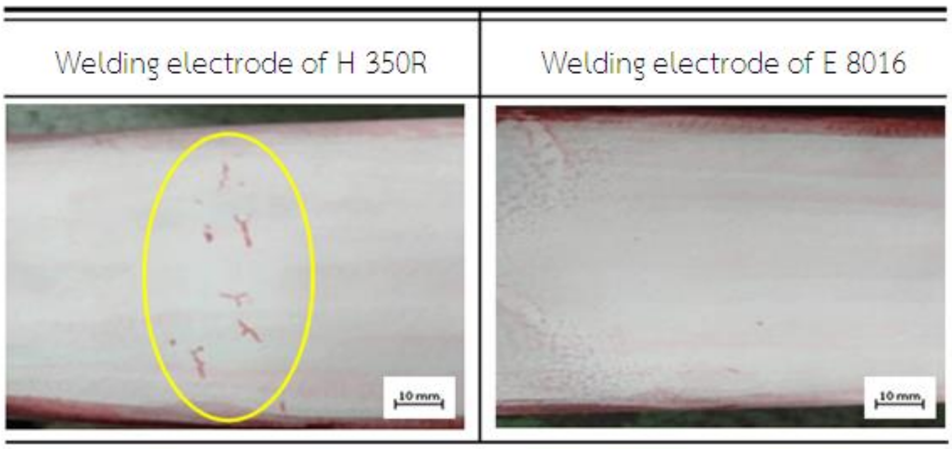

Figure 3 Examine the top welding surface with penetrant testing (PT)

5.2 Examine the cross-section surface with penetrant testing (PT)

Figure 4 Examine the cross-section surface with penetrant testing (PT)

From examining the cross-section surface with penetrant testing in welding with H350R, 1 - 2 millimeter long crack was found in welding zone as shown in Figure 4 (oval) which occurred while welding in each line and the crack was on top surface of the welding zone. Because heating level in welding space was definitely different (Hee-jin, L. Hae-woo, L., 2015) and the property of electrode with high amount of carbon caused contraction of welding substance, it was less flexible than E8016. From welding with electrode E8016, the welding line was more harmonious and there was no crack or porosity. This was because of mechanical property of high tensile strength and flexibility of the electrode.

5.3 Macrostructure examination

From the macrostructure examination shown in Figure 5, there was no noticeable crack or porosity. However, the heat-affected zone (HAZ) in welding with electrode H305R was narrower than welding with E8016. This is because the chemical property of the H305R electrode had more carbon than E8016. Its melting point directly affected heating while welding (Hee-jin, L. Hae-woo, L., 2015) that also decreased the capability of welding. However, from examining welding zone and heat-affected zone in welding with both electrodes, there was no crack line in both areas.

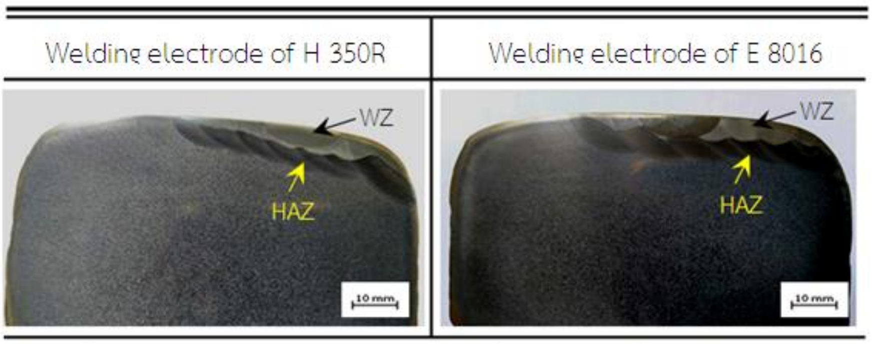

Figure 5 Macrostructure examining in welding zone (WZ) and heat-affected zone (HAZ)

5.4 Microstructure examination

Figure 6 showed the microstructure examination of base metal of railway steel 100 pound/yard which primarily consisted of Pearlite structure (black and white) which related to shape and space. The black area was Cementite (Fe_3C) and the white area was Ferrite (α) (Allie, A. Aglan, H. Fateh, M., 2010). Since the microstructure consisted of Pearlite structure around 85 - 95% , this railway steel had high mechanical properties in both hardness and tensile stress.

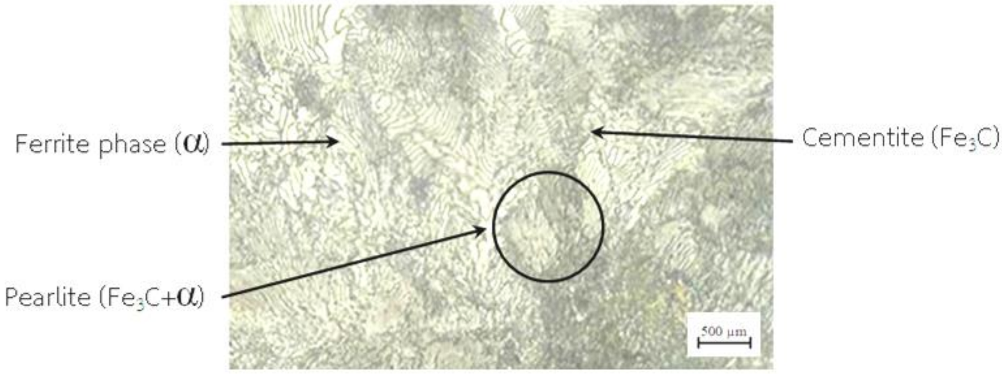

Figure 6 Microstructure examining of base metal (BM)

Figure 7 was the microstructure examination of welding zone. The structure of welding with both electrodes consisted of Pearlite structure (black and white). This occurred from slow cooling mixed with Banite structure (Black) (Wetscher, F. Leoben., 2007). Some parts might cool speedily due to the amount of carbon from railway material and electrodes. In addition, in welding with E8016 which contained high amount of silicon (Si), the grain was rougher than welding with H350R. However, welding with H350R caused 500 - 1,200 micron wide crack (oval) in welding zone which correlated to results from the investigation of welding surface with penetrant testing. As a result, it could be seen that welding with H350R electrode was not suitable for surface hard-facing welding of railway steel 100 pound/yard.

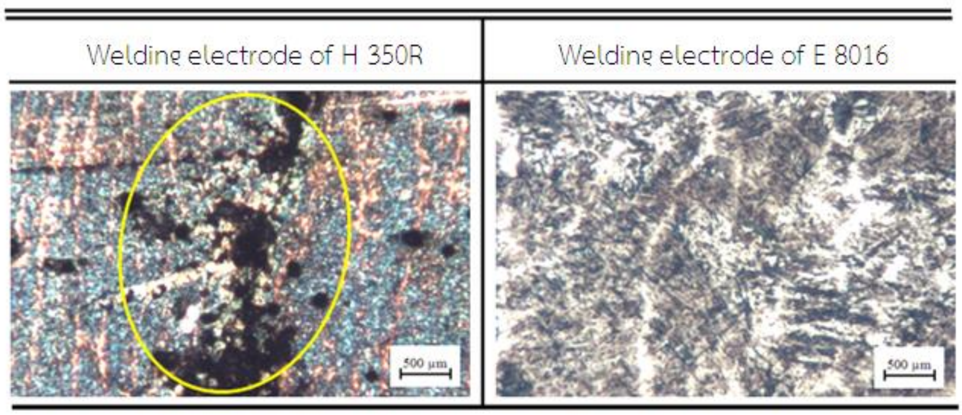

Figure 7 Microstructure examining in welding zone (WZ)

Figure 8 showed the microstructure examination in heat-affected zone. There was no crack from welding with both electrodes. The microstructure consisted of Ferrite (white) mixed with Martensite (black) evenly dispersing. This occurred because of the rapid cooling down (Amini, K. Bahrami, A. Sabet, H., 2015). On the other hand, Martensite structure in welding with H350R was more thoroughly than with E8016. This is because the amount of carbon in the electrode affected phase change of heating process to be more Martensite. However, in welding with E8016 with a large amount of silicon (Si) and manganese (Mg), the grain was rougher than welding with H350R. It also positively affected friction resistance, tensile strength and vibration.

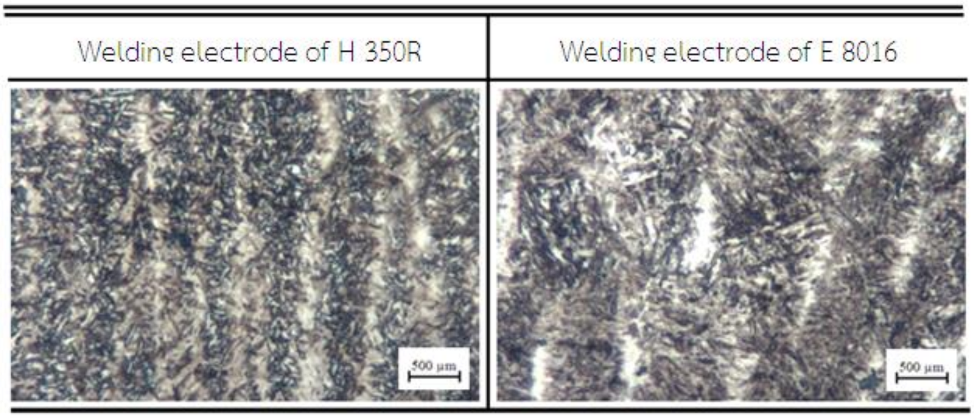

Figure 8 Microstructure examining in heat-affected zone (HAZ)

6. Acknowledgements

I would like to thank the Faculty of Agricultural and Industrial Technology, Phetchabun Rajabhat University, Phetchabun Province in supporting the research tools and materials. Moreover, special thanks to Mr. Pichai Watthanasrimongkol, engineer of Khon Kean Permanent Way Maintenance Division, State Railway of Thailand, as well as Asst. Prof. Dr. Prapas Muangjunburee from the Department of Mining and Materials Engineering, Faculty of Engineering, Prince of Songkha University, for their assistance in information and railway materials in this research.

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