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A Comparative Study on Corrosion Behaviors of Pearlitic Rails Generally Used in Railway Tracks

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ARTICLE INFO **ABSTRACT**

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This study aims to compare corrosion behaviors of four different quality rails which are generally preferred in railways. Potentiodynamic corrosion test and immersion test were performed for R260, R260Mn, R260 Grooved and R350HT quality rails. Microstructures of specimens were characterized by Scanning Electron Microscope (SEM) before and after corrosion tests. With this study, effects of chemical composition, rail geometry and heat treatment on corrosion performances of rails were investigated. Results show that R260Mn quality rail exhibits best corrosion performance among the rails. The Same trend could be observed by immersion test.

KEYWORDS: ***Rails, Corrosion, SEM***

1. Introduction

C-Mn rail steels (0.7-0.8 wt. pct. carbon) are called conventional and these steels are given an example for pearlitic rails[1]. Pearlitic rails are generally preferred because of their good mechanical properties such as fatigue behavior and wear performance [2]. However, eutectoid rails have poor corrosion resistance especially in coastal locations [3]. Pearlitic structure reduces the corrosion resistance due to the presence of high amount of cementite in pearlite microstructure renders the structure susceptible to enhanced corrosion[4]. Thus, corrosion may lead to cause big economic problems for countries because the life of pearlitic rails is reduced. Also, this situation is considered theserious cause of damage railway track[5].Normally, it is an expected from rails that works to approximately 15-20 years under normal traffic conditions. However, corrosion cases which are pitting formations or crevice at the rail foot under the liners reduce the mechanical life of rails so damage problems can occur before theestimated life of rails [6].

S. Samal et al. [7]studied the effect of marine and acidic environment on corrosion and mechanical properties of pearlitic rail steels.The results concluded that tensile strength decreases with increasing corrosion rate in marine and acidic environment. However, yield strength decreases with increasing corrosion rate in themarineenvironment while yield strength increased with increasing corrosion rate in anacidic environment. In another study, V. Rault et al. [8]investigated corrosion behavior of heavily deformed pearlitic and brass-coated. It was observed that plastic deformation had asmall influence on cathodic reactions (oxygenreduction reaction) while plastic deformationhad asignificant influence on anodic dissolution for both the pearlitic steel and the brass-coated steel.In one study about hydrogen embrittlement

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of microalloyedrail steelswere studied by A.P. Moon et al [9]. The results showed that the degree of embrittlement was higher in C–Mn rail steel compared to microalloyed rail steels.In another study belonging to A.P. Moon et al. [10] waspresented that conventional C-Mn rail steels have lower corrosion resistance than high-strength bainitic rail steels.

The aim of this study is to compare electrochemical corrosion behaviors of four quality rails in sodium chlorite solution. In this study, thenot only effect of chemical composition was investigated but also effects of rail geometry and heat treatment were evaluated.

2. Experimental Studies

2.1 Materials

In this study, four quality railswere used to make acomparison of corrosion behaviors.The chemical compositions of rails are shown in Table 1.

Table1. Chemical composition of rails

Rail Type		%					
		C	Si	Mn	P	Cr	V
Conventional Shaped	R260	0.70	0.15	0.90	0.01	0.08	0.10
	R350HT	0.70	0.15	0.88	0.01	0.08	0.09
	R260Mn	0.60	0.14	1.45	0.01	0.09	0.09
Grooved	R260	0.69	0.14	0.90	0.01	0.08	0.10

R260 and R260Mn quality rails havesame chemical composition except for manganese content and their hardness values are nearly 260-300 HBW [11]. While R260 quality rails are generally used in railways, R260Mn quality rails are generally preferred in narrow areas where the welding process is commonly necessary [12]. The third quality rail is R350HT which is used for fast train rails. This quality rail is produced by applying heat treatment to R260 quality rail [13]. Heat treatment is performed for head parts of rails with an accelerated cooling during production stages, this treatment is called as head hardening process. R350HT rails have 350 HBW hardness value on head part and exhibit better wear and mechanical properties compared than other rails due to sudden cooling [14]. The last rail used in this study is grooved rail which is preferred in tramlines [15]. The geometries of these quality rails are shown in Fig.1.

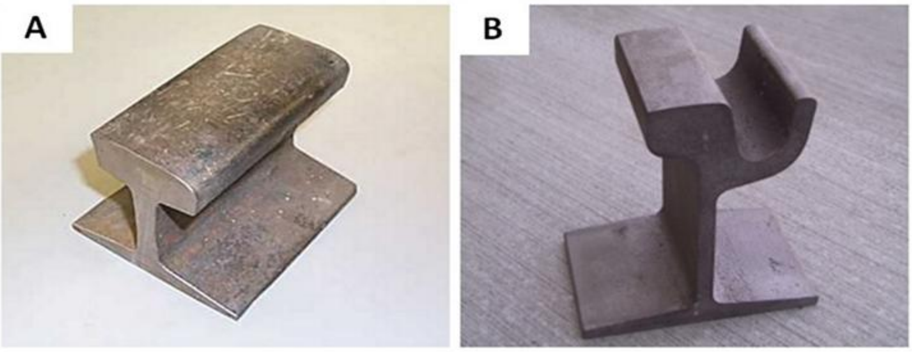

Figure 1. Geometries of used rails (a) R260, R260Mn and R350HT (b) R260 Grooved[11].

2.2 Characterization

Samples were mechanically ground from 60 to 2000 grit emery papers. After grinding, specimens were polished with 6 µm, 3 µm, and 1 µm diamond suspension respectively. Etching processwas applied by 3% nital solutions (nitric acid and alcohol). Microstructures of samples were analyzed by Scanning Electron Microscope (SEM). Corrosion tests were performed using potentiodynamic polarization method in 0.1M NaCIelectrolyteat room temperature with using a Parstat 4000 potentiostat test device controlled by a computer with Versa studio analysis software.Applied potential was between -0.9 V and -0.2 V relative to saturated calomel electrode (SCE) with 5mV/s. scanning rate. In addition to electrochemical corrosion test, immersion tests were applied for all rails and samples were waited at 1 day in 0.1M NaCI solutions. Corrosion rates were calculated manually and calculation was based on weight loss of samples. Weight loss of rails was calculated using sensitive electro balance with the resolution of 0.1 mg. Furthermore, SEM was used to understand the nature of corrosion after analyses.

3.Results

3.1. Microstructure analysis:

SEM microstructures of rails are shown in Fig.2.R260 quality rail has fully coarse pearlitic structure. Fig.2b) indicates theR260 groovedrail that consists of pearlite and α-ferrite.R350HT rail has same chemical composition but the structure is full of fine pearlitic. The distance between lamellar is lower that can be seen in Fig.2c) This is a result of sudden cooling of head parts. R260Mn rail has nearlysame microstructure with R260 because carbon contents are slightly lower but manganese content is higher according to the Table 1. It can be deduced that α-ferrite is much moredistributed than R260 quality rail.

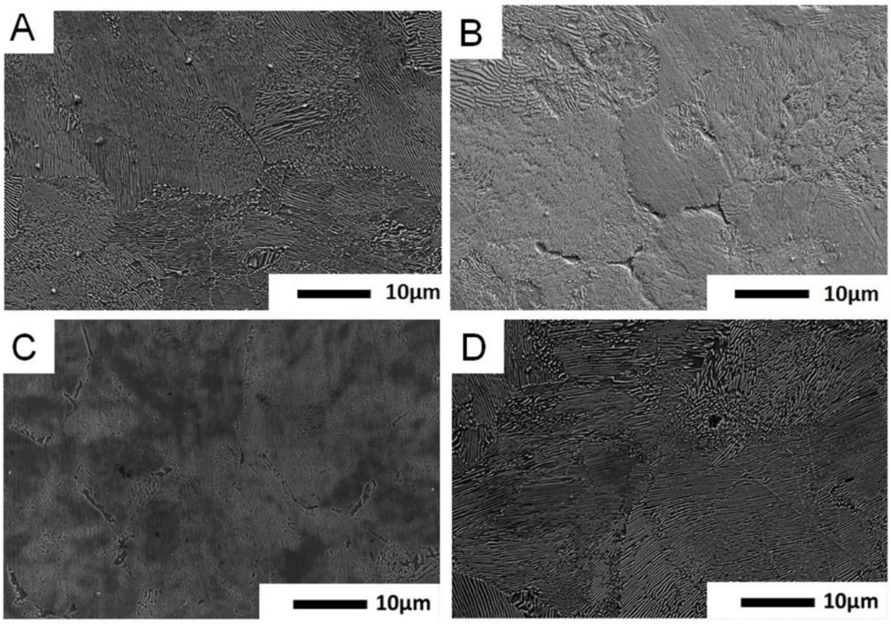

Figure 2. SEM micrographs of rail specimens (a) R260, (b) R260Mn, (c) R350HT, (d) R260 Grooved

3.2. Corrosion Results:

The potentiodynamic polarization curves for the samples in 0.1MNaCI solution isgiven in Fig. 3. Tafel kinetic couldn’t be observed in anodic regions, so only cathodic currents were considered for linear Tafel extrapolations to obtain corrosion current.

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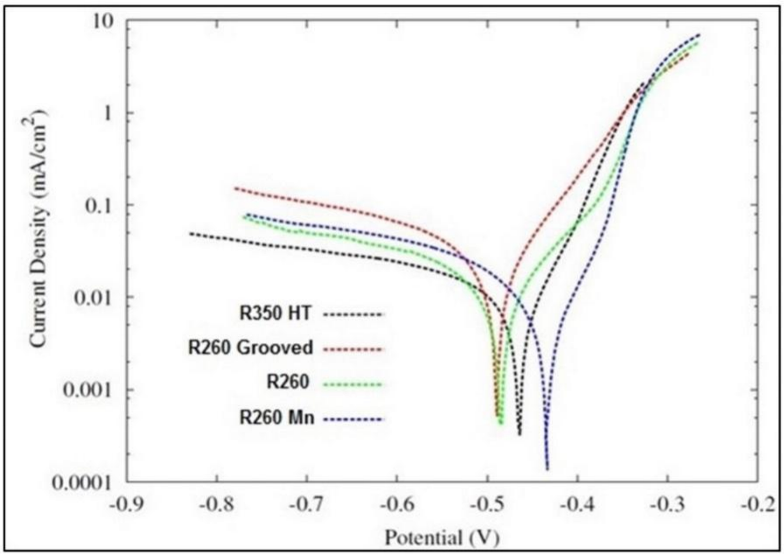

Figure 3: Tafel plot of rails

I_{corr} values determined from extrapolations are used to calculate corrosion rates of the samples according to following equation[12]:

Corrosion Rate (mm/year) = λ. icorr.(E.W.) / d.

Where;

λ = 3.27 x 10^{-3}(mm. g) / (mA . cm . year) is a metric conversion factor

E.W. = Equivalent Weight

d = Density (g/cm^3)

The results derived from individual fittings have been presented in Table 2.

Table 2: Corrosion results of different quality rails

Rail Type		E_{corr}(V)	i_{corr}(mA/cm^2)	Corrosion rate (mpy)
Conventional Shape	R260	-485	0.012	5.67
	R350HT	-465	0.010	4.90
	R260 Mn	-434	0.008	4.17
Grooved	R260	-490	0.017	7.70

Results have revealed that R260Mn quality rail shows best corrosion resistance among the rails. This is a result of lower carbon content which can exhibit cathodic effect that enhances the corrosion rates. When the corrosion performances of other rails have about to same chemical compositions are examined, thecorrosion rate is lower for R350 HT rail. Therefore, heat treatment (head hardening process) have positive affect both mechanical properties and corrosion performance of rails. Corrosion current is the highest in R260 grooved rail so this rail is susceptible to corrosion. Plastic deformation and groove formation in head part of rails effect the corrosion performance negatively. According to Vignal et al., plastic deformation in pearlitic steels leads to increase in thedensity of dislocations and formation of one more than preferential crystallographic directions. Thus, corrosion sensitivity getsincrease after plastic deformation[8].

However, immersion test was performed during 72 hours in 0.1MNaCI electrolyte. Results are presented in theFig.4exhibit the same trend with electrochemical corrosion test. Weight loss in thesample is the highest in R260 grooved rail so these quality rails are prone to corrosion.

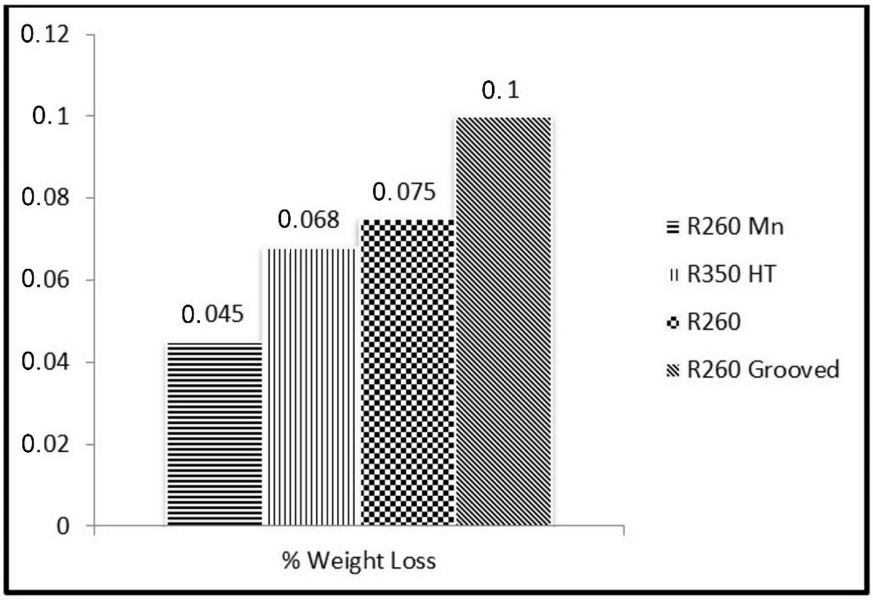

Figure 4: Immersion test results of samples

It can be seen that from Fig. 5d), R260Mn has exhibited best corrosion resistance when the corroded surfaces are evaluated. Pitting corrosions are dominant mechanism especially for R260 grooved quality rail. Pitting corrosions and partially rust formationsurround thewhole surface of this specimen. R350 HT shows better corrosion resistance than other rails (R260 and grooved) which have about same chemical compositions. These results predict that the corrosion resistance of specimens has increased with thedecrease of pearlite lamellar distance. The cooling process also has affected to corrosion behavior of rail.Because R350 HT has been produced by suddenly cooling of head parts of R260 quality rail.

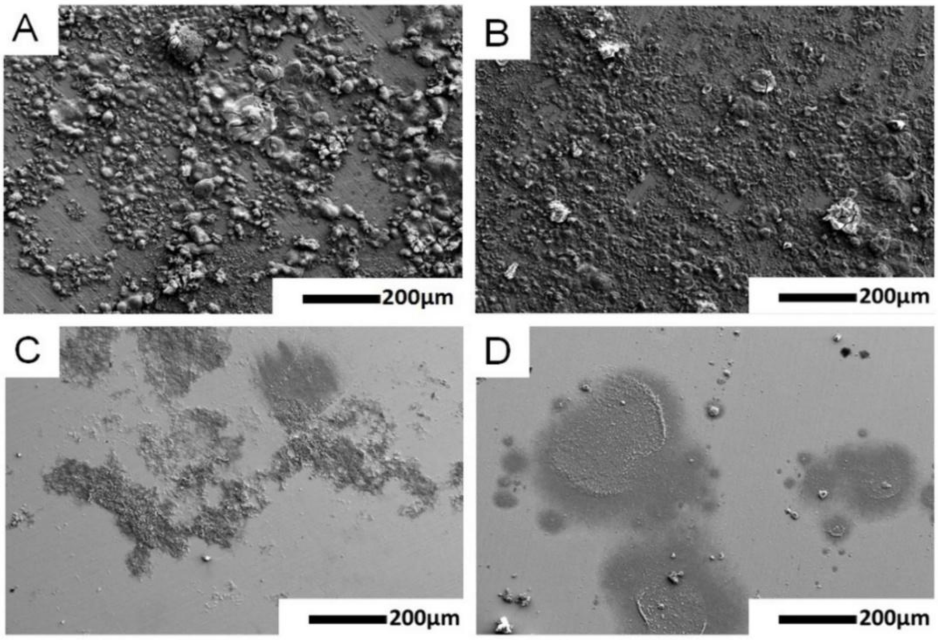

Figure 5: Corrosion surfaces of samples

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4. Conclusions

Electrochemical corrosion tests and immersion tests were performed for all rails in NaCI electrolyte. All results are considered, R260Mn has the best corrosion performance among the rails because of the lower carbon content. Besides, heat treatment onrail head of R260 quality has apositive effect on corrosion behaviors. On the other hand, plastic deformation of rail head enhances the corrosion current so R260 grooved rail has poor corrosion resistance compared to other rails.

5. Acknowledgement

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