Atlantis Highlights in Intelligent Systems (AHIS), volume 1
3rd International Conference on Control, Automation and Artificial Intelligence (CAAI 2018)

Preliminary Study Influence of Wear on High Temperature Oxidation Performance of U71Mn Rail Steel

Yanjun Xi*, Xianzhe Li, Yongjun Liu, Ying Liu, Xiaoyan Guan and Haiqing Jiang
School of Materials and Chemical Engineering, Zhongyuan University of Technology, Zhengzhou 450007, P.R.China
*Corresponding author

***Abstract*—The objective of this study is to preliminary explore the effect of wear on high temperature oxidation performance of U71Mn rail steel. The specimens was tested at 500 N on abrasion testing machine, and then performed at high temperature in the furnace. The surface and cross section was investigated by SEM with EDS. Oxide phase was analysized by XRD. The results showed that deep scratches on wear samples cause the oxide film to fall off seriously, so that the weight gains at high temperature is smaller than that of the non-wear samples. The oxide is rough, unstable and exfoliated easily. The oxidation rate of U71Mn after wear is higher than that without wear. Therefore, the high temperature caused by frequent friction plays an important role in the service life of high-speed trains.**

Keywords—wear; high temperature oxidation; U71Mn; rail steel

I. INTRODUCTION

Since 1980s, high speed trains have appeared in France and Germany, promoting the high speed of the main trunk lines in Europe. Then high speed railway construction is rapidly rising [1-3].

The existing research shows that the friction heat is one of the most important factors that cause damage of the rail when high speed train passes[4-9]. Wheel/ rail temperature rise will aggravate wheel rail abrasion, and even make a phase change of rail material, resulting in cracks on the rail surface, causing damage and spalling[10-11].

During the operation of high speed railway, friction heat is produced by the relative sliding of wheel and rail[12-16]. The friction heat is concentrated in the contact area of the wheel and rail, which makes the temperature of the contact area rise rapidly. Vo K D, Naeimi M and Shebani A have studied the friction temperature rise of wheel/ rail through numerical simulation. It is considered that the maximum temperature of the wheel /tread contact area is about 900°C [17-20].

According to the literature on wheel rail friction temperature rise, the wheel /rail friction temperature raises at least 800 °C. Although the high temperature duration of the material is very short, the material will undergo rapid oxidation at a high temperature under sufficient oxygen conditions. The train operation has a strong impact on the rail, and the friction may cause great damage to the oxide or the matrix, which directly affects the service life of the rail. This problem has not been reported yet. Therefore, this paper studies the process of forming high temperature oxide after friction, which has important guiding significance for understanding the failure evolution of rail.

II. EXPERIMENTAL DETAILS

In this study, samples are cut into 15mm×15 mm×15 mm from original U71Mn steel using wire cutting machine. Grinding with sand paper, polishing and cleaning are carried out.

Wear tests are performed on abrasion testing machine. The force of 500 N is adopted to simulate the contact stress between the wheel and rail. The wear tests elongated for 30 S with 500 N or 1000 N. the sample is taken down and weighed. Then the sample is loaded for other 30s test. The total time is 300s.

High temperature oxidation tests are carried out with wear and non-wear samples. The corrosion morphology and the phase structure of corrosion products were characterized by optical microscopy, scanning electron microscopy with energy dispersive and XRD.

III. RESULTS

A. *Test Results of High Temperature Oxidation*

Figure I is the macro morphology of U71Mn at 800°C after 5h. Gray brittle oxide layer is formed on the surface, which may be Fe_3O_4. The oxide layer is almost completely peeled off from the lower oxide. When we just touch it, it falls off in the form of slag. The oxide of the lower layer can clearly show brownish red, which may be Fe_2O_3.XRD also proved the existance of Fe_3O_4 and Fe_2O_3, as shown in Figure II.

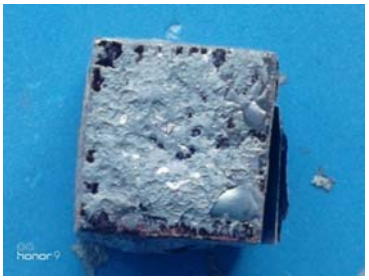

FIGURE I. MACRO MORPHOLOGY OF U71MN AT 800°C AFTER 5H

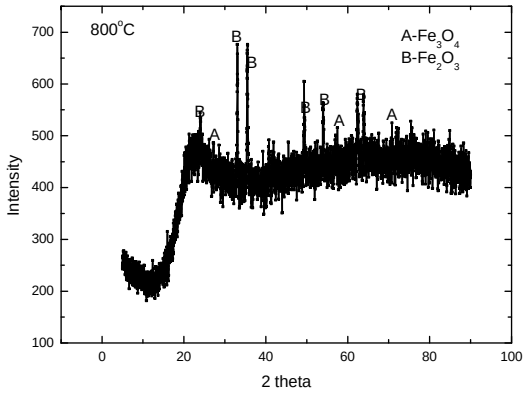

FIGURE II. XRD OF U71MN AT 800°C AFTER 5H

The cross section SEM observation of U71Mn at 800°C for 5h is carried out. As shown in Figure III, the total thickness of the oxide layer is about 120μm. The bonding force between the outer layer and the subsurface layer is very poor. There are a large number of voids and holes, which is one of the reasons for peeling off of outer layer. EDS analysis indicate that outer layer mainly contains Fe and O, with a partial C and a small number of Mn. The component of outer layer is 27.44Fe-58.33O-13.98C-0.26Mn, as shown in Figure IV. The outer layer may be Fe_3O_4. The XRD also proves the existence of Fe_3O_4.

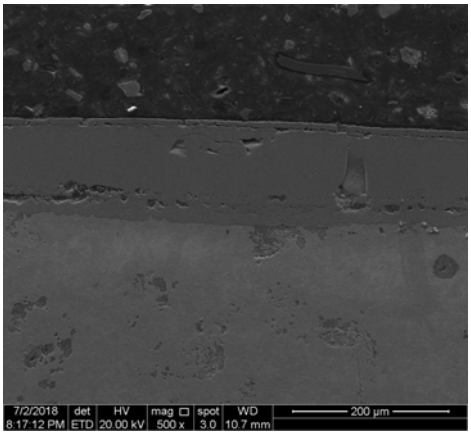

FIGURE III. CROSS-SECTIONAL SEM OF U71MN AT 800°C AFTER 5H

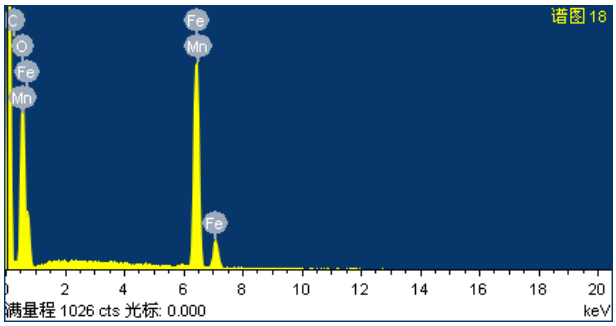

FIGURE IV. EDX OF OUTERMOST LAYER OF U71MN AT 800°C AFTER 5H

Figure V is the macro morphology of wear samples after 500 N for 300 s at 800°C for 5h. The surface produces black oxide, mainly Fe_3O_4. The color is uneven, the doping of some brick red and gray white, which is mainly Fe_2O_3 and FeO. Because these oxides grow faster, the particles are larger, the surface is rough, and the oxidation layer is uneven, brittle. The oxide is bulge, so some areas have already fallen off.

Friction causes plastic deformation and cracks on the surface of U71Mn rail along the longitudinal direction. The oxygen in the air is adsorbed and enriched at the tip of the crack. The high temperature oxide reduces the binding force of the grain boundary atoms and reduces the binding energy of the atomic bond at the crack front. The crack surface energy can be reduced and the crack growth is accelerated. At the same time, the oxide will quickly fall off with the crack.

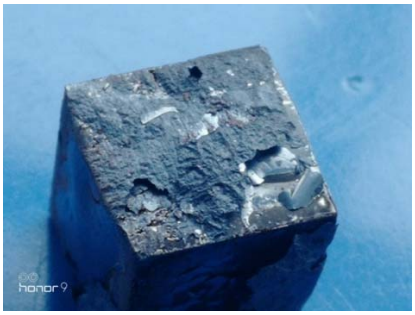

FIGURE V. MACRO MORPHOLOGY OF WEAR SAMPLES AFTER 500 N FOR 300 S AT 800°C FOR 5H.

IV. CONCLUSIONS

(1) Serious oxidation of U71Mn occurred in a short period of high temperature.

(2) The deep scratches on wear samples cause the oxide film to fall off seriously, so that the weight gain of oxidation is smaller than that of the non-wear samples.

(3)After wear, the oxidation rate of U71Mn is higher than that without wear. Therefore, the high temperature caused by frequent friction plays an important role in the service life of high-speed trains.

ACKNOWLEDGEMENT

This research was financially supported by the Natural Science Foundation Project of Henan Province (182300410231).

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