Available online at www.sciencedirect.com

SCIENCE DIRECT®

JOURNAL OF IRON AND STEEL RESEARCH, INTERNATIONAL. 2006, 13(5): 60-64, 78

Effect of Rare Earth on Void Band of Diffusion Layer and Properties of Aluminized Steel

ZHANG Wei[1,2,3], FAN Zhi-kang[1], HU Peng-fei[2], LONG Yong-qiang[3], LIU Hua[2], WEN Jiu-ba[3]

(1. School of Materials Science and Engineering, Xi'an University of Technology, Xi'an 710048, Shaanxi, China; 2. Department of Materials Engineering, Luoyang College of Technology, Luoyang 471003, Henan, China; 3. School of Materials Science and Engineering, Henan University of Science and Technology, Luoyang 471003, Henan, China)

Abstract: The effects of the addition of rare earth (RE) elements on the void band in the diffusion layer, and the resistances to both oxidation and spalling of aluminized steel were investigated through high temperature oxidation and spalling tests. The results showed that RE had significant effects on the void band in the diffusion layer and the properties of aluminized steel. After diffusion treatment, a considerable number of the voids between the middle layer and transitional layer of pure aluminized coating, aggregated into wavy-line-shaped void bands parallel to the outer surface. For the RE-added aluminized coating, only a few voids aggregated into intermittent block shapes. During high temperature oxidation at 800 ℃ for 200 h, the wavy void band of pure aluminized coating aggregated further into a linear crack parallel to the outer surface, and the internal oxidation occurred within them; the open cracks perpendicular to the surface penetrated through the diffusion layer. For the RE-added aluminized coating, only a few voids aggregated into intermittent meniscus shapes. During cyclic spalling tests, the peeling, spallation, and pulverulent cracking occurred along the void band in the diffusion layer of pure aluminized coating, but only a little spallation occurred in the diffusion layer of the RE-added aluminized coating, in which cracks perpendicular to the surface were much smaller than those of pure aluminized coating and did not penetrate through the diffusion layer. It is evident that RE addition can restrain the formation and aggregation of voids and subsequently improve the resistances to oxidation and spalling. The mechanism of the RE effect on the void band in the diffusion layer is also discussed.

Key words: rare earth; void band; crack; internal oxidation; oxidation resistance; spalling resistance; aluminized steel

Hot dip aluminized steel (HDA-steel) is applied gradually because of its better oxidation and corrosion resistance[1]. However, its aluminized layer is brittle and the adhesion ability of Al_2O_3 film is poor, which accelerates the degeneracy of aluminized layer and reduces its lifetime[2,3]. The oxidation and spalling resistance of HDA-steel can be enhanced with RE-added aluminizing, but until now its mechanism is not very clear, and much attention has been paid to it. RE can improve the plasticity of aluminized layer and the adhesion ability of Al_2O_3 film, and promote a protective oxidation film to form[3-6]. No reports have been found until now on the effect of RE on the void band and internal oxidation in the diffusion layer of aluminized steel. Therefore, the effects of RE on the void band in diffusion layer and properties of aluminized steel have been studied by means of high temperature oxidation and spalling tests to provide a theoretical basis for enhancing high temperature oxidation resistance and spalling resistance, and improve the further application of the RE aluminized steel.

1 Experimental Condition

The specimens with dimensions of 50 mm×30 mm×3 mm are made of 20 steel plate, A_{00} industrial pure aluminum with a purity of 99.7% and the RE aluminum alloy with lanthanum of 0.3%.

Foundation Item: Item Sponsored by Key Science and Technology Plan Foundation of Henan of China (0423023500) and Natural Science Foundation of Henan Province (0511021600)

Biography: ZHANG Wei(1957-), Male, Doctor, Associate Professor; **E-mail**: weizhang57@163.com; **Revised Date**: March 6, 2006

The HDA procedure is: degreasing→rinsing→derusting→rinsing→activating→drying→hot dip aluminizing. HDA was performed at 740 ℃ for 3 min. Diffusion treatments were carried out at 900 ℃ for 6 h and the specimens were cooled down in the furnace.

High temperature oxidation tests were conducted in a box-type furnace at 800 ℃. Oxidation time was 5 h, 10 h, 20 h, and 40 h, respectively. The specimens were cooled to 400 ℃ in the furnace, and then cooled to room temperature in air each time. The process of cyclic spalling test was as follows: first, the specimens were oxidized at 600 ℃ for 30 min in air, then rapidly quenched in distilled water at 20 ℃, and finally weighed at room temperature after being dried at 150 ℃. An electronic balance with allowance of 0.000 1 g was used to measure the mass change of high temperature oxidation and spalling specimens. The kinetics curves of oxidation and cyclic spalling were plotted based on the data of mass changes.

Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used to analyze the surface morphology and composition of the coating.

2 Experimental Results

2.1 High temperature oxidation kinetics

Fig. 1 shows the kinetic curves of the coating oxidized at 800 ℃ for 200 h in air. It is obvious that the changes of mass are obviously different, and the growth rule of kinetic curves is different under the conditions of aluminizing with or without RE. Experimental results reveal that the curve of pure aluminized coating is a parabola before 40 h, that is, mass increases quickly at first and then slowly, and after 40 h, it is linear with a higher oxidation rate. For the RE-added aluminized coating, the oxidation kinetic curve obeys the parabola growth rule and its mass increase is less than that of pure aluminized coating during the whole oxidation. When the specimens were oxidized for 200 h, mass increase of the RE-added aluminized coating was two-third of that of pure aluminized coating.

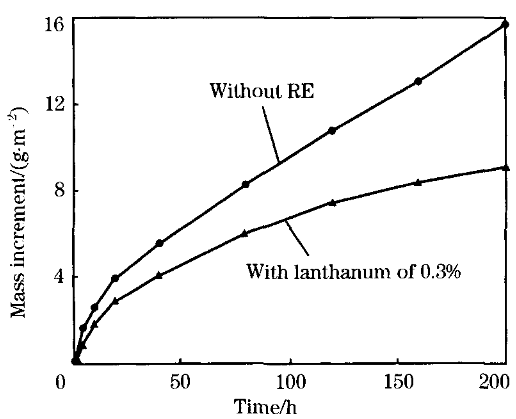

Fig. 1 Kinetics curves of specimens oxidized in air at 800 ℃ for 200 h

2.2 Cyclic spalling resistance

The curves of mass change of the specimens oxidized at 600 ℃ and quenched in distilled water are shown in Fig. 2. It is obvious that the mass loss of specimens with pure aluminized coating is severe when oxidized and quenched in distilled water for the first time. Hereafter, mass loss gradually reduces and fluctuates more greatly with increasing cyclic spalling time. For the RE-added aluminized coating, the mass loss is always less compared to that in pure aluminized coating for the first time and it increases a little for the second time, but the total mass loss of two cyclic spallation is still less than that of the pure aluminized sample. In subsequent circles, the mass loss reduces smoothly and slowly. It indicates that the RE-added aluminizing can enhance the spalling resistance of aluminized coating.

2.3 Microstructure

The analysis of the microstructure and composition of specimens shows that whether adding RE or not, the diffusion layers are all divided into three parts after diffusion treatments, as shown in Fig. 3. The outer surface layer is black and there are a large number of voids in it. Under the outer surface layer,

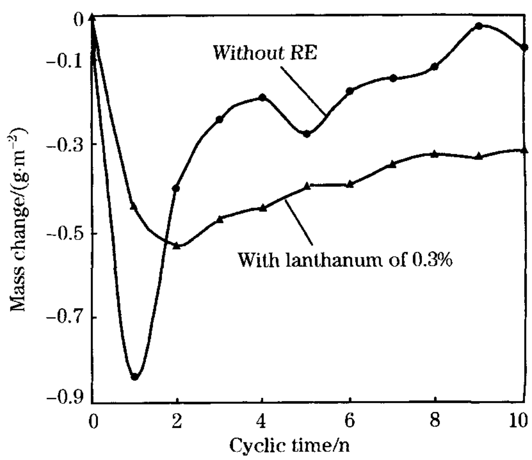

Fig. 2 Mass change of specimens oxidized at 600 ℃ and quenched in distilled water