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Investigation of Properties of Hot-dipped Ce-rich Rare Earth Aluminum Alloy upon Conditions of Corrosion Environment*

WEN Jiu-ba, LI Quan-an, ZHAO Wan-xiang, WANG Zhi-hui
(*School of Materials Science and Engineering*,
Henan University of Science and Technology, *Luoyang* 471003, *China*)

Abstract: The effect of rare earth on microstructure components and corrosion-resistance of hot-dipped aluminum was studied. The results showed that the microstructure was homogenized, the forehead edge of hot-dipped layer became smooth with the increase of the rare earth content in the range of 0.1% ~ 0.5%, but the thickness of diffused layer began obviously decrease when the content was more than 0.5%. The hot-dipped layer with 0.3% rare earth possessed best microstructure characteristic and corrosion-resistance. The corrosion resistance of the hot-diffused layer with 0.3% rare earth was 2 ~ 3 times as much as that with 0% rare earth.

Key words: rare earth; aluminum alloy; hot-dipped aluminum
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1 Introduction

Hot dipped aluminized steels possess favorable resistance to heat, corrosion resistance and wear resistance characteristic in oxidability and corrosion medium[1,2]. At the same time it keeps the mechanical properties of matrix material, therefore, they are extensively applied to metallurgy, electric power, petrochemical industry and so on[3]. Owing to the specific atomic structure and peculiar physical property, the properties of materials will be changed obviously while adding minor rare earth, rare earth has obtained clearly success in the region of materials[4-6]. Whereas, the study of the effect of rare earth on corrosion-resisting properties of hot dipped aluminized steels is less. Our advanced research shows that rare earth has excellent characteristics in improving corrosion resistance of aluminized workpiece, especially at severe rugged environment conditions (H_2S, high temperature etc.). In order to open up the application frontier of rare earth, the effect of different additions of mixed rare earths on corrosion-resisting properties of aluminized coating at subacidity media has been researched by means of hot dipped aluminized method in this paper.

2 Experimental

2.1 Materials

Rare earth aluminum alloy used in the present work were fabricated by A_{00} industrial pure aluminum (w = 98.5%) and rare earth-aluminum intermediate alloy which the content of rare earth element was 10% and rich-Ce. Adjusted the composition, the content of rare earth in aluminum alloy was 0.1%, 0.3% and 0.5%, respectively. A commercial 20 carbon steel was used as the substrate material. The steel plate was machined into rectangular specimens with dimensions of 65 mm × 20 mm × 2 mm.

2.2 Experimental procedure

The specimens were precleaned before being hot-dipped. The procedure involved rinsing the specimens in 5% hydrochloric acid solution for approximately 10 ~ 15 s, followed by water rinsing and drying.

The specimens were then dipped in a molten flux bath containing 60% KCl and 40% NaCl. The molten flux was maintained at 700 ℃ and the time of dipping in the flux bath was 3 min. This fluxing treatment was down in order to enhance wetting and minimize the dissolution of the specimen into the molten rare earth aluminum bath.

The specimens were then immediately dipped into a molten rare earth aluminum bath. This bath was maintained at 730 ℃. The time of hot-dipping was 3 min and the specimens were constantly vibrated inside the bath to ensure good wetting. At the end of the dipping period, the specimens were rapidly withdrawn and allowed to cool in air.

The specimens were then given a diffusion treatment at 850 ℃ for a period of 4 h. The rare earth aluminum coating obtained by this process was about 200 μm.

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Corresponding author: clxya@mail.haust.edu.cn(WEN J B)

The corrosion resistance of aluminizing layer was evaluated by weight loss of corrossion. The specimens were immersed in 3.5% NaCl + 1.5% Na_2S supersaturated H_2S solution (open to air). The solution was maintained at pH 6.8 at 40 ℃. The corrosion time was selected from 10 to 90 hours.

The JOEL JSM-5610LV scanning electron microscope (SEM) was used for observing the microstructure, and the SEM with energy spectrum for investigating the distribution of alloy content, the phase structure of the rare earth aluminizing layer was determined using X-ray diffractometer.

3 Results and discussion

3.1 The microstructure of the hot-dipped aluminized coating

Pretreated at 730 ℃ for 3 min, the samples are hotly dipped in aluminum alloy with different ingredients, and obtained the hot-dipped aluminized coatings. Fig.1 is the microstructure of the hot dipped aluminized samples. Whether adding rare earth or not, the surface coating has comprised two parts, the outer layer enriches in aluminum, its ingredients are the same as that of aluminum alloy's; while the second out layer enriches in aluminum and iron as well as a little of intermetallics of $FeAl_3$, Al_2O_3, FeO, $FeAl_3$ in the aluminized coating, the primary ingredient of it is the metallic compound Fe_2Al_5. In the rare earth free coating, the intermetallics dive into steel's matrices by means of comb type, the combs are very thin whereas possess obvious orientation, its thickness is about 50 ~ 80 μm.

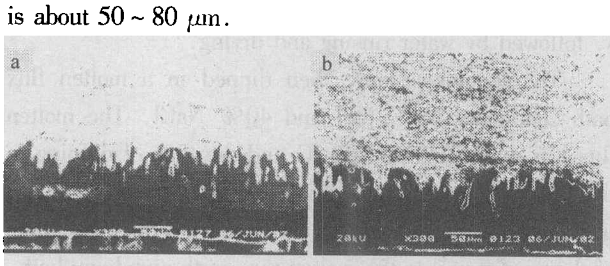

Fig.1 The microstructure of hot-dipping coating before diffusion
a: without rare earth; b: with 0.3% rare earth

Fig.2 is the microstructure of the aluminized coating, which has been hotly dipped at 850 ℃ 4 hours' diffusion treatment. It has two layers from the surface to center after diffusion treatment, the first layer, which is formed by means of moving to the matrix from the aluminized coating during the thermal diffusion process, the "wave" interface between the two layers may be caused by the diffusion of the transition interface between the aluminized coating and the comb layer. The second layer, which is formed by the transverse diffusion of the comb structure, is relatively brighter than that of the first layer. The alloy layer with rare earth whose diffusion layer is comparable thicker, and its microstructure is uniformly, the diffusion is plenitude, which shows that adding rare earth can promote the diffusion of aluminum in the matrix at diffusion temperature. Furthermore, within the limits of 0.1% ~ 0.5% RE contents, in company with the contents of rare earth increasing, the microstructure of coating becomes relatively uniformly, and the thickness of diffusion layer increases, especially the thickness attaches most at 0.3% RE content. Whereas the thickness of diffusion layer wanes when the content of rare earth exceeds 0.5%. In a word, whether having diffused or not, the microstructure of the coating is satisfactory at 0.3% RE content.

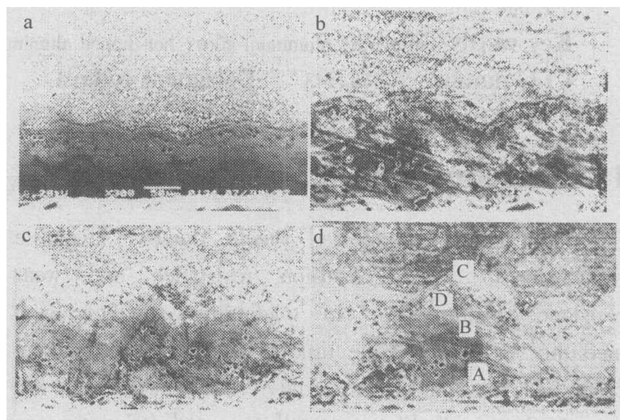

Fig.2 The microstructure of hot-dipping coating after diffusion at 850 ℃ for 4 h
a: without rare earth;
b: with 0.1% rare earth;
c: with 0.3% rare earth;
d: with 0.5% rare earth

3.2 Analysis of the ingredient and phase of diffusion layer

The test measured the average chemical composition of the aluminized coating containing 0.5% rich cerium rare earth by X-ray energy spectrum instrument. Fig.3 is the result of it, which shows that the alloy constituents of the coating are Al, Fe and RE. It also illustrates that the aluminized coating maintaining little rare earth element is formed on steel surface after diffusing at 850 ℃ for 4 h. Tab.1 is the result of the measurement on the alloy consti- tuents at differnt position (Fig.2d) of aluminized coating which containing 0.5% rich cerium rare earth. The result shows that the surface layer of hot dipped coating still possesses upper aluminum and rare earth after diffusion treatment, the rare earth contents decrease and iron content increase inwardly. The XRD phase analysis (Fig.4) show that, the diffusion layer is composed of Fe_2Al_5, $FeAl_3$, Fe_3Al, $FeAl_2O_4$ etc. There is no FeAl phase spectrum strung in the diffusion layer, which may be caused by the inferior content of FeAl.

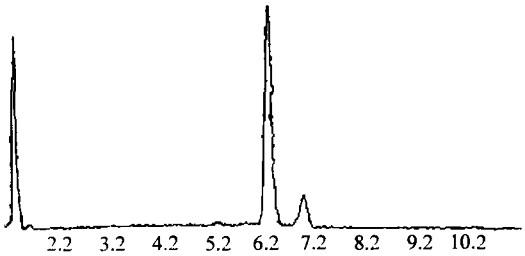

Fig.3 EDAX result of diffusion layer with 0.5% RE

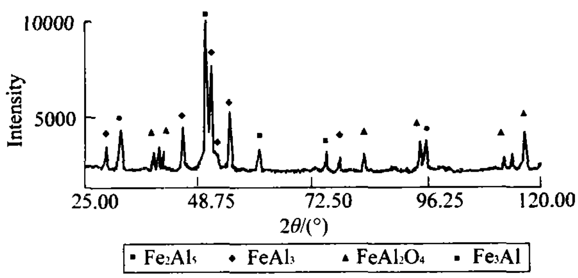

Fig.4 XRD Patterns of diffusion layer of hot-dipped aluminum with 0.5% RE

3.3 Corrosion resistance test

Corrosion resistance tests of the aluminized diffusion layers which containing different rare earth have been done. Fig.5 is the relation curve between corrosion weight loss and etching time. The results show that corrosion weight loss of pure aluminized coating increases as a linear, that is to say that erosion aggravates in company with time prolongs, and corrosion resistance increases after adding rare earth. The corrosion resistance of the aluminized coating containing 0.1% RE and pure aluminized coating has no obvious difference, it increases distinctively with the rare earth content in the range of 0.3% ~ 0.5%, the aluminized coating containing 0.3% RE possesses best corrosion resistance which is about as much as that with 0% rare earth.

Adding rare earth can increase the corrosion resistance of aluminum alloy, especially under the condition of severe corrosion, which is mostly caused by the following factors. Firstly, rare earth can improve the adhesivity of the immersion metal and matrix, and integrate the coating, and improve the homogeneity, both compactness and plasticity of the aluminized coating.

Secondly, stable compound layer which is formed above interface combined with rare earth and environmental corrosion atmosphere (such as sulphureous deep-etching atmosphere) or matrix element prevents the corrosively atmosphere from the inside. Thirdly, rare earth ameliorates the density and integrality of Al_2O_3 in the surface of aluminized coating, and restrains alloying oxygenation, and transfer corrosion potential of the aluminum alloy. Further studies are on the underway.

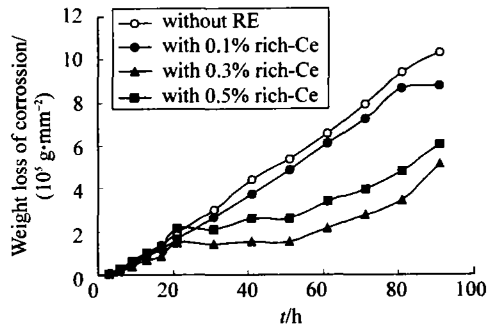

Fig.5 Corrosion weight loss *vs*. time for coatings with Ce-rich rare earth after diffusion

3 Conclusions

Surface modification by hot-dipped rare earth aluminum improved the corrosion resistance of steel. The microstructure was homogenized, the forehead edge of hot-dipped layer became smooth with the increase of the rare earth content in the range of 0.1% ~ 0.5%, but the thickness of diffused layer began obvious decrease when the content was more than 0.5%. The hot-dipped layer with 0.3% rare earth possessed best microstructure characteristic and corrosion-resistance. The corrosion resistance of the hot-diffused layer with 0.3% rare earth was 2 ~ 3 times as much as that with 0% rare earth.

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热浸镀富铈稀土铝合金的耐腐蚀性研究

文九巴,李全安,赵万祥,王志辉

(河南科技大学材料科学与工程学院,河南 洛阳 471003)

摘　要:研究了富铈稀土对碳钢热浸镀铝合金组织及耐腐蚀性的影响。结果表明,在稀土含量为0.1%~0.5%范围内随着稀土含量的增加热浸镀层组织均匀,当稀土含量超过0.5%时扩散层厚度明显减小,稀土含量0.3%的热浸镀层具有最好的组织,并且在酸性介质腐蚀条件下具有最好的耐腐蚀性。含0.3%稀土的热扩散层的耐腐蚀性比纯铝提高2~3倍。

关键词:稀土;铝合金;热浸镀铝

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