Influence of oxides on high velocity arc sprayed 
Fe-Al/Cr$_2$C$_2$ composite coatings

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Abstract: Fe-Al/ Cr$_2$C$_2$ coatings were sprayed on low steel by high velocity arc spraying (HVAS) technology. The influences of oxides on erosion, corrosion and wear behavior for high velocity arc sprayed Fe-Al/ Cr$_2$C$_2$ coatings were studied. The results show that HVAS-sprayed Fe-Al/ Cr$_2$C$_2$ coatings have good erosion, heat corrosion and wear resistance. The erosion resistance improves with the increase of the temperature. On one hand, the ferrous oxides are incompact, so they peel off the surface of the coatings easily during the high temperature erosion. On the other hand, compact Al$_2$O$_3$ films on the surface can protect the coatings.

Key words: oxides; Fe-Al/ Cr$_2$C$_2$ coating; arc sprayed; corrosion resistance; wear property

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1 INTRODUCTION

Arc spraying (AS) is a technique that the metal is heated to droplets by an electric arc and then sprayed onto substrates by the compressed air. High velocity arc spraying (HVAS) technology is developed on the basis of AS. A special tube designed according to the principle of aerodynamics is mounted at the exit of compressed air. The velocity and distribution of melted droplets become higher and more uniform, respectively. As a result, a coating with low porosity (2%) and high density and bond strength can be obtained\(^{1-5}\). Fe-Al intermetallic compound is an ideal high temperature framework material because of its high temperature anti-oxidation property, sulfuration resistance, elevated temperature strength and low density\(^{6-10}\). However, the bad ductility at room temperature and the low fracture strength have limited its application. Fe-Al intermetallic compound coatings with reinforced phases prepared by HVAS technology can improve the property of Fe-Al alloys\(^{11-15}\). Therefore, using the HVAS technology on the surface of materials is one of the main measures to prevent their corrosion.

In this paper, Fe-Al/ Cr$_2$C$_2$ coatings were sprayed on low steel by HVAS technology. The erosion, heat corrosion and wear properties of the coatings were studied.

2 EXPERIMENTAL

The experimental material used in the present study was 1020 steel. The sprayed material was Fe-Al/ Cr$_2$C$_2$ cored wire with 3 mm in diameter. The Fe-Al/ Cr$_2$C$_2$ coatings were sprayed by CMD-AS300 type HVAS equipment and HAS-01 torch. The spraying voltage and current were 32 V and 180 A, respectively. The blasting distance was 300 mm and the atomization pressure was 0.43 MPa.

The erosion properties of the coatings were tested on the GW/CS-MS high temperature erosion equipment in atmosphere environment. The range of temperatures was from room temperature to 650 °C. The wear particle was 125 ~ 175 g quartz sand with a size of 250 μm. The wear velocity was 62 m/s. The impact angle was 30° and 90°, respectively. The erosion time was 75 ~ 90 min.

The mass increase was measured by using a TG328B photoelectric analytical balance at different time. The Na$_2$S$_2$O$_3$ and K$_2$S$_2$O$_7$ with a mole ratio of 7 : 3 saturated solution was the corrosive that smeared on the samples. The density of the formed saline coatings on the surface of sample is 2 ~ 3 mg/cm$^2$. The samples were dried and weighed before heating. Then they were heated to 450, 650 and 800 °C, respectively. And they were weighed at room temperature again. This process was repeated until the total heat time reached 200 h. The rate of weight gain (Δm) can be calculated by Eqn. (1).

\[
\Delta m = \left( \frac{m_{i+1} - m_i}{A} \right) - \left( \frac{m_{i+1} - m_i}{A} \right) \times 0.6
\]  \hspace{1cm} (1)
where \( i \) is the times of corrosion; \( m_i \) is the weight of samples without corrosive before corrosion; \( m_{i+1} \) is the weight of \( i \) samples with corrosive before heating; \( m_{i+2} \) is the weight of samples after heating, \( A \) is the area of sample.

The high temperature wear behavior of the samples was tested by TH T07-135 ball-disk wear equipment. A 3 mm diameter \( \text{Si}_3\text{N}_4 \) ball was used as the mating material. The sliding speed was 0.8 m/s. The wear diameter and distance were 5 mm and 500 m, respectively. The load was 5 N. The samples were heated to 200, 250, 300, 450, 550 and 600 °C, respectively.

The compositions of coatings were investigated by energy dispersion spectroscopy (EDS) using scanning electron microscope (SEM) and transmission electron microscope (TEM, H800).

3 RESULTS AND DISCUSSION

3.1 Effects of oxides on erosion behavior

Fig. 1 shows the results of EDS for HVAS-sprayed \( \text{Fe-Al/Cr}_3\text{C}_2 \) coatings eroded at 450 °C and 650 °C, respectively. It shows that the oxides are formed on the surface of coatings, which are mainly \( \text{Al}_2\text{O}_3 \) films. In the process of high temperature erosion, the surface temperature is above the experimental temperature. Therefore, the oxides are formed easily, which are mainly ferrous, aluminum and chromic oxides. The ferrous oxides are relative incompact and easily peel off the surface under the action of quartz sand. And the element of \( \text{Cr} \) can improve the growth of \( \text{Al}_2\text{O}_3 \). As a result, the densely \( \text{Al}_2\text{O}_3 \) films are formed on the surface. The \( \text{Al}_2\text{O}_3 \) films can enhance the erosion resistance of coatings. Erosion results at different temperatures are shown in Fig. 2. It shows that corrosion resistance enhances with the increase of the temperature.

![Fig. 2 Erosion resistance of samples](#)

3.2 Effects of oxides on heat corrosion resistance

Heat corrosion resistance and EPS images of the coatings are shown in Fig. 3 and Fig. 4, respectively. It shows that coatings have better heat cor-

![Fig. 3 Heat corrosion resistance of samples](#)
rosion resistances than the matrix. Cr$_2$O$_3$ has so low conductivity that it improves the corrosion resistances of the coatings. The main mechanism is that Cr$_2$O$_3$ can increase the growth speed of Al$_2$O$_3$ on the coatings. On the other hand, the higher the temperature (800 °C) is, the more quickly the oxides are formed. Fig. 4(d) shows that ferrous oxides mainly exist on the surface of the coatings and the Al$_2$O$_3$ exist on the deeper level of the coatings.

3.3 Effects of oxides on wear property

Fig. 5 shows the wear properties of the H V A S-sprayed Fe-Al/Cr$_3$C$_2$ coatings. With the increase of the temperature, the friction coefficient of coatings decreases and the wear rate changes slightly. The results of EDS for coatings at different temperatures are shown in Table 1. With the increase of the temperature, the content of oxygen increases and the content of ferrous decreases. It shows that the coatings are oxidized during the wear test. Because the ferrous oxides are incompact, they peel off the surface of the coatings easily. And some of them are sintered, oxidized and adhered to the surface again. It decreases the wear ratio and protects coatings. On the other hand, compact Al$_2$O$_3$ films can enhance the wear property of coatings. When the temperature is above 550 °C, which is the working temperature range (550~980 °C) of Cr$_2$O$_3$, the coatings maintain better wear resistance due to the good high temperature prosperity of Cr$_2$O$_3$.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Results of EDS analysis for coatings at different temperatures (atom fraction, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ/°C</td>
<td>25</td>
</tr>
<tr>
<td>O</td>
<td>4.42</td>
</tr>
<tr>
<td>Al</td>
<td>12.78</td>
</tr>
<tr>
<td>Fe</td>
<td>67.62</td>
</tr>
</tbody>
</table>
4 CONCLUSIONS

HVAs-sprayed Fe-Al/Cr3C2 coatings have good erosion resistance, heat corrosion resistance and wear property. The erosion resistance enhances with the increase of the temperature. On one hand, because the ferrous oxides are incompact, they peel off the surface of the coatings easily during the high temperature erosion. On the other hand, compact Al2O3 films on the surface can protect coatings.

REFERENCES


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