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Effects of RE oxide on the microstructure of hardfacing metal of the large gear

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ABSTRACT

The Rare Earth (RE) oxide was added into the electrode coating for hardfacing large gear and the microstructures of the hardfacing specimens with and without RE oxide were observed by using optical microscopy (OM). Meanwhile, the matrix phase of the hardfacing metals was determined by using X-ray diffraction (XRD) and the fractographs as well as inclusions were observed and analyzed by using scanning electron microscopy (SEM) with energy dispersive spectrum (EDS). The results show that, the microstructure of the hardfacing metal is mainly composed of the fine acicular ferrite, and the fracture surface is uniform and fine dimple exists on the fractograph of the specimen with RE oxide. The inclusions become spherical ones, which are distributed in hardfacing metal dispersively. However, the microstructure of the hardfacing metal is composed of coarse acicular ferrite and pearlite, and the fractograph is composed with dimple and quasi-cleavage in the specimen without RE oxide.

Large gear is an important workpiece for industry production, which is usually manufactured by low carbon steel (such as steel 20CrMnTi) [1] or medium carbon steel (such as steel 45CrMnMo and 42CrMo) [2]. The shape and size of the failed large gear can be restored by means of remanufactured technologies, in which, the hard-face-welding (hardfacing) is one of the best effective methods [3,4]. During hardfacing process, by using conventional electrode, the large gear should be heated to about 400 °C before hardfacing and re-heated after hardfacing, otherwise, the cracks will occur on the hardfacing metal and heat affected zone (HAZ) of the large gear. For the pre-heating and post-heat treatment of the large gear, whose dimension is larger than 4 m, it is difficult to manufacture the large heat treatment furnace and the hardfacing technology is more complicated.

Therefore, it is of great significance to develop a new kind of electrode, by which, the hardfacing of the large gear can be carried out practically without pre-heating or post-heat treatment.

The effects of RE oxide on the hardfacing metal of medium-high carbon steel (MHCSs) such as hot roller steel 60CrMnMo and hot die steel 5CrNiMo have been carried out, in which, the microstructure of the hardfacing metal is mainly composed of martensite after hardfacing [5,6]. However, that of the hardfacing metal is mainly composed of ferrite or pearlite of low or medium carbon steel, and the effect of RE oxide on the hardfacing metal of the large gear has not been reported.

Based on the above-mentioned research work, the RE oxide was added into the electrode coating and the effect of RE oxide on the microstructure of the hardfacing metal of the large gear was observed, by which, the prescriptions of the electrode can be further optimized. Therefore, the hardfacing of the large gear can be carried out without pre-heating and post-heat treatment.

1. Experiment materials and methods

1.1. Manufacture process of electrode and hardfacing technology

H08A steel was selected as the electrode core in this work, whose chemical composition is listed in Table 1. Two prescriptions of electrode are listed in Table 2. According to previous works, the addition of RE oxide in the electrode coating for hardfacing the large gear is 1.7 wt.%.

The low hydrogen $CaCO_3$–CaF_2–SiO_2 slag system was employed for electrode coating. The alloy additions are mainly composed with Mo–Fe, Mn–Fe, Ti–Fe, Si–Fe, Cr–Fe and Ni–Fe. The parameters of the electrode based on above prescription are listed in Table 3.

The manual arc hardfacing method was used to weld on the gear surface. The hardfacing technology parameters are listed in Table 4. Two different electrodes were employed separately for hardfacing based on hardfacing technology. Two specimens were prepared for each electrode and four layers were welded for each specimen.

1.2. Observation of the microstructure

The metallographic specimens were prepared after grinded, then corroded with 4% nitric acid spirit of alcohol. The microstructure of the hardfacing metal and the binding site of the specimens were observed by using optical microscope of type 4XA. The fractograph of the hardfacing metal was observed by scanning electron

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Table 1
Chemical composition of H08A steel.

Element	C	Mn	Si	Cr	Ni	S	P
Content	≤0.1	0.3–0.5	≤0.03	≤0.2	≤0.3	≤0.03	≤0.03

Table 2
Composition of the coating of hardfacing electrode.

No.	Mn	Cr	Mo	RE oxide	Ni
1#	1.4	4.6	2.1	1.7	1.1
2#	1.4	4.6	2.1	0	1.1

microscope (SEM) of type KYKY2800 and the inclusions were analyzed by energy dispersive spectrometer (EDS) of type KEVEX LEVEL4.

2. Experimental result

2.1. Microstructure and X-ray diffraction of the hardfacing metal

The microstructures of two hardfacing metals are shown in Fig. 1. The microstructure of the specimen with RE oxide is mainly composed of fine acicular ferrite, which is shown in Fig. 1(a). That of the specimen without RE oxide is the coarse acicular ferrite and partial pearlite, which is shown in Fig. 1(b).

The X-ray diffraction (XRD) patterns of the hardfacing specimens with and without RE oxide are shown in Fig. 2. It can be seen that, the matrix phase of the hardfacing metal with and without RE oxide are both composed of α-Fe. Meanwhile, the FWHM (full width at half maximum) of each peak was analyzed by Jade5 software, which is listed in Table 5. It can be seen from Table 5 that the FWHM with RE oxide are larger than that of without RE oxide, which indicates the grain is refined.

2.2. Binding sites between hardfacing metal and matrix

The binding sites between the hardfacing metal and the matrix of two specimens are shown in Fig. 3, in which, the hardfacing metal (H) is shown on top half and matrix (M) on bottom one.

There are no cracks, air holes or other defects in the binding sites between hardfacing metal and matrix. The binding is excellent, which is metallurgical one.

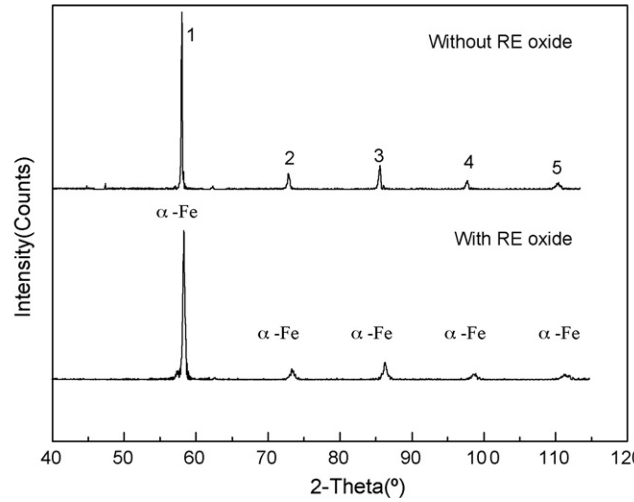

Fig. 2. XRD of hardfacing specimen with and without RE oxide.

Table 4
Welding technology parameters.

Welding current	Coating type	Open circuit voltage	Arc voltage
150–200 A	Low hydrogen type	40 V	28–33 V

Table 5
Comparison of FWHM of each peak (μm).

Peak	1	2	3	4	5	6
Without RE oxide	0.216	0.394	0.408	0.407	0.412	0.750
With RE oxide	0.384	0.443	0.615	0.603	0.638	1.005

2.3. Fractograph of the hardfacing metals

The fractographs of two hardfacing specimens are shown in Fig. 4. From Fig. 4(a), the fracture of specimen with RE oxide is plastic one. The fracture surface is uniform and fine dimples can be found on the fractograph. From Fig. 4(b), the dimple rupture and quasi-cleavage appear on the fracture surface of the specimen without RE oxide. River patterns, secondary cracks and tearing ridges are

Table 3
Parameters of the electrode.

Outer diameter of electrode	Diameter of electrode	Length of electrode	Gravity coefficient of coating	Deposition coefficient
6.6 mm	4.0 mm	320 mm	44%	66%

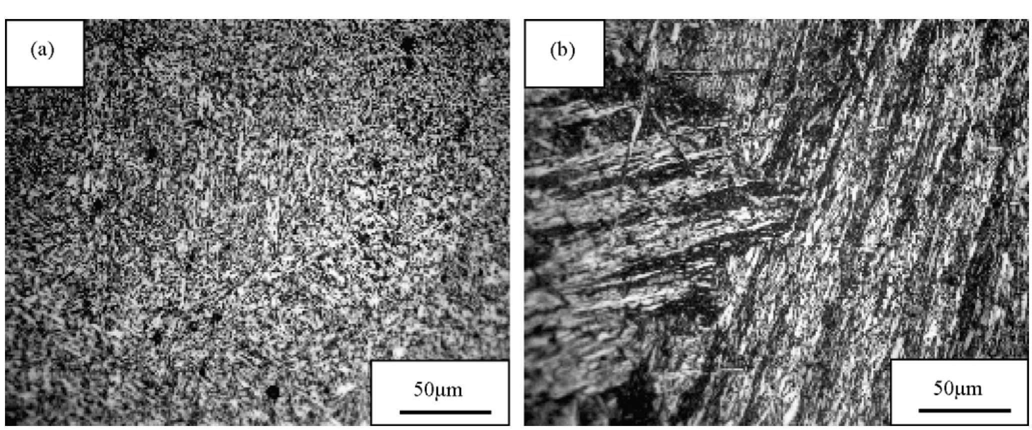

Fig. 1. Microstructures of the hardfacing metals (a) with RE oxide and (b) without RE oxide.