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Effect of La_2O_3 on granular bainite microstructure and wear resistance of hardfacing layer metal

WANG Yajun (王亚军)[1], CHEN Jigang (陈继刚)[2], YANG Jian (杨 健)[1], HAO Feifei (郝飞飞)[3], DAN Ting (淡 婷)[3], YANG Yulin (杨育林)[2], YANG Qingxiang (杨庆祥)[1,*]

(1. State Key Laboratory of Metastable Materials Science & Technology, Yanshan University, Qinhuangdao 066004, China; 2. College of Mechanical Engineering, Yanshan University, Qinhuangdao 066004, China; 3. Capital Aerospace Machinery Corporation, Beijing 100076, China)

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Abstract: The purpose of this work was to investigate the effect of La_2O_3 on the granular bainite microstructure and wear resistance of hardfacing layer metal. The hardfacing layer metals with different contents of La_2O_3 were prepared. The microstructures of the hardfacing layer metals were observed by field emission scanning electron microscopy (FESEM) and transmission electron microscopy (TEM). The hardness and wear resistance of the hardfacing layer metals were measured respectively. The results indicated that with the increasing content of La_2O_3, the amount of granular bainite increased, while that of martensite decreased and that of retained austenite did not change obviously. When the content of La_2O_3 was 2.55 wt.%, the volume fraction of the granular bainite in the hardfacing layer metal was 73.2%. Meanwhile, the wear resistance of the hardfacing layer metal was the largest, which was 12100 min/g. The mismatch between the face (100) of $LaAlO_3$ and the face (100) of δ-Fe was 7.1%. Therefore, $LaAlO_3$ could act as moderate effective heterogeneous nuclei of δ-Fe and the granular bainite could be refined.

Keywords: La_2O_3; granular bainite; wear resistance; heterogeneous nuclei; rare earths

In 1920, Robertson found a transformation microstructure during mesothermal isothermal process, which was defined as bainite[1]. Some researchers have proved that the bainite steel shows a good comprehensive property[2–4]. In recent years, granular bainite containing orientated martensite-austenite (M-A) constituents and lath ferrite (LF) shows a good function in the steels. Because granular bainite steels have better and comparable wear resistance, they are considered as the candidate materials and have been applied successfully[5–7].

In order to enhance the properties of the steel workpiece surface, the hardfacing techniques by welding were applied commercially[8]. If the microstructure of the hardfacing layer metal is composed of bainite, its comprehensive mechanical properties such as strength and toughness can be improved largely. However, the bainite in the steel is usually obtained during isothermal process. It is difficult to obtain the bainite during hardfacing process because it is a continuous cooling process.

Moreover, the strength of the steel depends on the grain size, and a higher worn surface hardness was claimed to have much higher wear resistance[9–11]. It has been established that both the toughness and strength are improved markedly if the grain size can be reduced to 1–2 μm[12], which have been proved widely[13–16]. Rare earth (RE) can influence the grain size largely. Meanwhile, it can influence the shape, size and distribution of precipitated phase by microalloying. Many researches have been carried out to study the effect of RE to improve the properties of steel[17–19]. In addition, the researches have showed that the bainite/martensite microstructure had the best performance with respect to both sulfide stress cracking (SSC) and hydrogen-induced cracking (HIC) susceptibility[20,21]. However, the reports about effect of RE element on the microstructure and wear-resistance of hardfacing layer metal containing bainite are seldom.

RE element is very active, which is even oxidized in air. It is impossible to add RE element into the hardfacing layer metal, so La_2O_3 (RE oxide) was chosen in this paper. The effect of different contents of La_2O_3 on the microstructure and wear resistance of the granular bainite in the hardfacing layer metals were investigated systematically, in order to understand of the relationship between the different contents of La_2O_3 and the refinement of granular bainite.

1 Experimental

The hardfacing layer metals for hardfacing bainite

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* **Corresponding author:** YANG Qingxiang (**E-mail:** qxyang@ysu.edu.cn; **Tel.:** +86-335-8387471)

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steel with different contents of La_2O_3 were manufactured. The powders of out coating were composed of ferrosilicon, nickel powder, ferromanganese, ferromolybdenum and so on. The additions of La_2O_3 were 0 wt.%, 0.87 wt.%, 2.55 wt.%, 4.18 wt.% respectively. The core steel of the hardfacing consumable was made of low carbon steel of H08A, whose composition is listed in Table 1.

Base metal for hardfacing layer metal was prepared from low carbon steel plates of Q235, and three layers were welded onto all specimens. The welding parameters are listed in Table 2. The chemical compositions of the base metal and hardfacing layer metals are listed in Table 3.

In order to analyze the effect of the content of La_2O_3 on the microstructure and wear resistance of the hardfacing layer metals, the color microstructure was observed by Axiovert 200 MAT optical microscope (OM) after being corroded by the mixed alcohol solution with 1 vol.% sodium pyrosulfite and 4% picric acid. The microstructure and worn morphology were observed by a Hitachi 3400 field emission scanning electron microscope (FESEM) after being corroded by 4% nitric acid alcohol after being polished metallographically. The phase structures were determined by D/max-2500/PC X-ray diffraction (XRD) with the angle from 20° to 120°, and the scanning velocity is 4(°)/min. The composition of each phase was analyzed by energy dispersive X-ray spectrometry (EDS). The granular bainite (M-A constituent and lath ferrite) was examined by a Jem 2010 transmission electron microscope (TEM) in detail.

Table 1 Composition of the H08A steel (wt.%)

Elements	C	Mn	Si	Cr	Ni	S	P
Composition	≤0.1	0.3–0.5	≤0.03	≤0.2	≤0.3	≤0.03	≤0.03

Table 2 Production process parameters of the hardfacing layer metals

Electric current/A	Voltage/V	Speed/(mm/s)
140–150	24–26	1.1–1.7

Table 3 Composition of the specimens and base metal Q235 (wt.%)

Elements	C	Mn	Si	Cr	Mo	Ni	La_2O_3	Fe
La_2O_3 (0)	0.46	0.5	0.4	0.92	1.26	2.16	0	Bal.
La_2O_3 (0.87)	0.45	0.5	0.39	0.94	1.28	2.16	0.87	Bal.
La_2O_3 (2.55)	0.46	0.52	0.39	0.9	1.26	2.18	2.55	Bal.
La_2O_3 (4.18)	0.47	0.5	0.4	0.93	1.28	2.16	4.18	Bal.
Q235	0.20	0.65	0.3	–	–	–		Bal.

2 Results

2.1 Microstructure characterization

2.1.1 SEM observation

The microstructures of the hardfacing layer metals with different contents of La_2O_3 are shown in Fig. 1, which mainly consists of the granular bainite, martensite and retained austenite. With the content of La_2O_3 increasing, the amount of the granular bainite increases, while, that of the martensite decreases, because the retained austenite can not be observed obviously here, we will discuss it later. Meanwhile, the granular bainite is

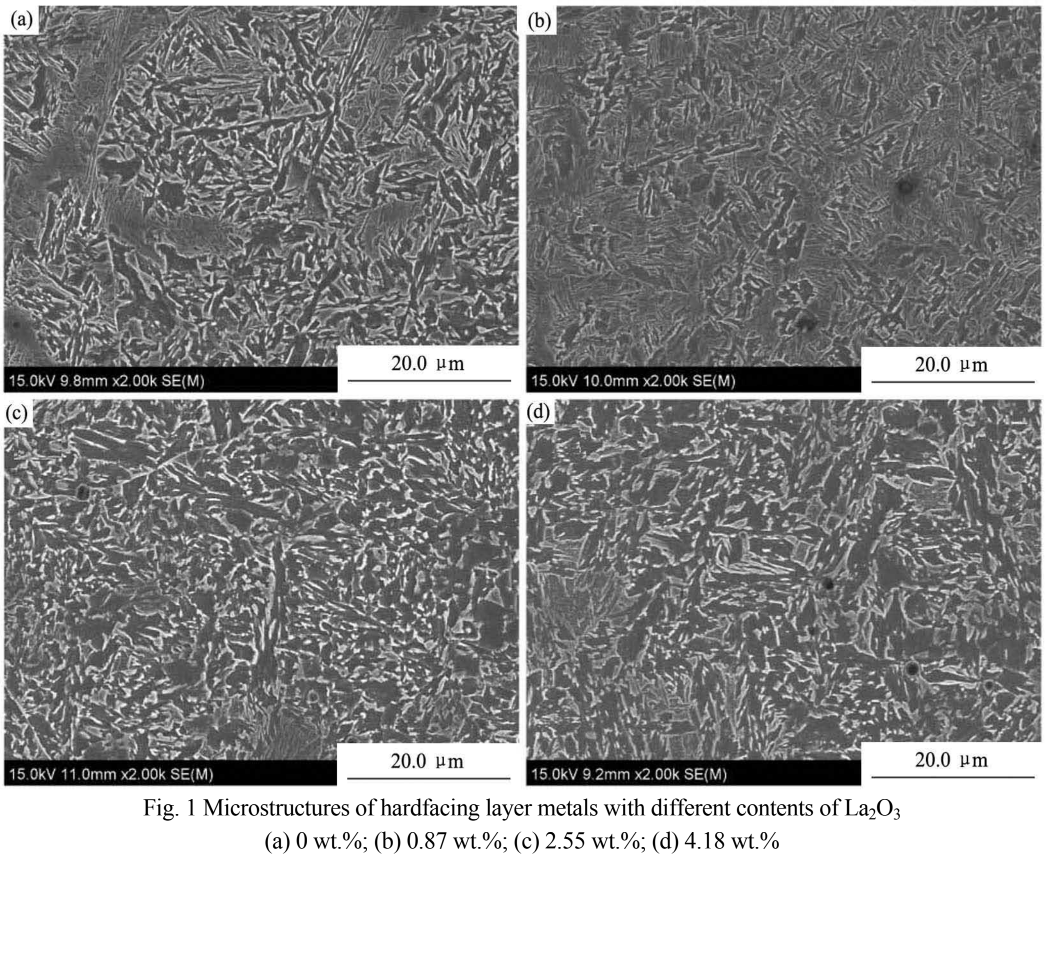

Fig. 1 Microstructures of hardfacing layer metals with different contents of La_2O_3
(a) 0 wt.%; (b) 0.87 wt.%; (c) 2.55 wt.%; (d) 4.18 wt.%