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Research on ion carbonitriding and wear resistance of cast iron

LI Jilin[1], ZHANG Fang[1], LI Yongjie[2]
[1]Institute of Materials Processing, Guangzhou General Research Institute for industrial technology, Guangzhou 510650, China; Guangzhou Yi Yin New Material Technology co., LTD,Guangzhou 510530, China;

In this study, the microstructure and phase, wear resistance of ion carbonitrided cast iron were investigated. Casting crankshaft consists of ductile cast iron and grey cast iron samples were subjected to quenching and tempering pretreatment. Ion carbonitriding were carried out at 570 ℃ for 6h, followed by cooling in the furnace. The result showed that there are bright layer which thickness is 120~210μm, appeared on the surface of samples. What's more, after ion carbonitriding, the hardness of samples were improved significantly which can enhance wear resistance greatly. In addition, in comparison with carbonitrided grey cast iron, wear resistance of carbonitrided ductile cast iron shown better performance.

Key words: *cast iron; carbonitriding; wear resistance;*

1. Introduction

In order to improve the hardness, abrasion resistance, fatigue resistance of the cast iron, chemical heat treatment on the surface are often used in industrial production. Carburizing, nitriding technique has been widely used in steel production. However, little information is available regarding the carbonnitriding technology applied to cast iron. In this paper, two different cast irons were both processed by the same carbonitriding method. Furthermore, compared these two kinds of cast irons which was processed by carbonitriding regarding their characteristics and wear resistance. The results of this paper strive to provide the theoretical basis for related theory and practical application.

2. Experimental

2.1 Experimental material

The chemical composition of the investigated are given in Table 1. Samples were divided into 5 groups, 1 #, 2 #, 3 # samples are different spheroidizing effect of centrifugal casting ductile iron samples, and, 4#, 5# are sand casting crankshaft gray cast iron. The 4# is HT250 (CuCr Low alloyed gray iron), 5# samples for HT300.

Table 1 Chemical composition of samples (wt. %)

	C	Si	Mn	S	P	Mg	Ce	Cu	Cr
1#	3.51	2.34	0.35	0.009	0.021	0.036	0.014	----	----
2#	3.54	2.48	0.35	0.015	0.022	0.036	0.014	----	----
3#	3.57	2.53	0.35	0.011	0.021	0.036	0.016	----	----
4#	3.30	1.86	0.92	0.020	0.050	----	----	0.52	0.22
5#	3.25	1.91	0.92	0.055	0.048	----	----	----	----

2.2 Experimental methods and procedure

Before ion carbonitriding, quenching and tempering treatment was necessary for all samples. All samples were quenching in the electric furnace with temperature 920 °C, holding 1.5 hours, followed by air cooling to room temperature. Then, tempering at 560 °C for 2h, followed by air cooling to room temperature.

Ion carbonitriding was carried out in the LDMC-50AQK plasma nitriding furnace at 560 °C for 6h; Wear resistance test was carried out in the UMT-3(Nano Tribometer) friction and wear pilot facility.

3. Result and analysis

3.1 Microstructure after ion carbonitriding

The microstructure after ion carbonitriding was shown in Fig1. After ion carbonitriding, there are birght layer and black diffusion layer appeared on the samples surface, and center for the matrix metal. It is similar to the microstructure of ion carburizing, nitriding structure. The matrix metal was tempered sorbite. In addition, compared with the samples without ion carbonitriding, Sorbite of the carbonitrided samples evenly distributed in the matrix metal and ferrite phase is almost disappeared. It illustrated that the carbonitriding process has benefit to restrain matrix metal grain growth .

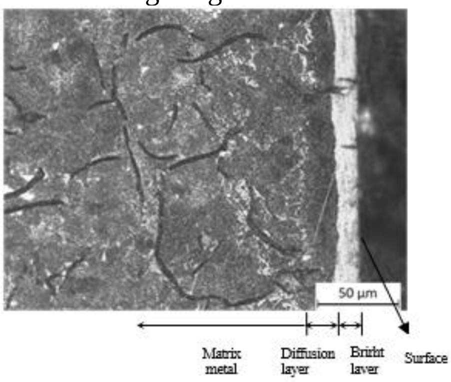

Figure 1 Microstructure of carbonitrided samples

3.2 The phase composition of carbonitrided surface layer

X-ray diffraction (XRD) spectrum of carbonitrided surface layer of 3#, 4# samples were shown in Fig 2 and 3. Both the ductile cast iron and grey cast iron have a multiphase structure, consisting of γ' (Fe_4N), ε (Fe_3N), Fe_3C phase. These compounds affected the chemical composition of the surface, which has played an important role in improving the performance of samples. In a vacuum furnace, adding DC between workpiece which is cathode and furnace wall which is anode to make the rarefied gas ionization for forming H^+, N^+, $C4^+$. Then, the accelerated ions bombard cathode work piece. In addition, ion carbonitriding has strong capability providing C, N. The characteristics of cast iron which containing high carbon and silicon, played an obstacles role in infiltration of C, N atoms of carbonitriding. Then, a series of reactions will take place in the workpiece surface. Fe will combine with C, N atoms to form Fe-C, Fe-N compound. Since the back scattering effect, Fe-N compounds deposited at the cathode surface again. Under the effect of ion bombardment and thermal activation, in turn, it will decomposes into Fe-Fe_2N-Fe_3N-Fe_4N, and producing active atoms, the active N atoms seeping into the work piece with existing active C atoms. Furthermore, because Fe_3C and ξ（Fe_3N）have a similar structure, C atoms can replace the N atoms from ξ（Fe_3N）,then get Fe_3C [1].

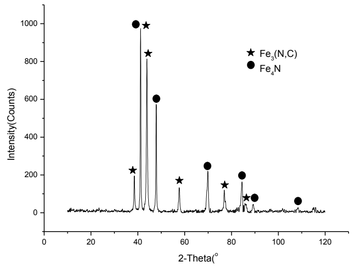

Figure 2 X-ray diffraction spectrum of carbonitrided surface layer of 3# samples

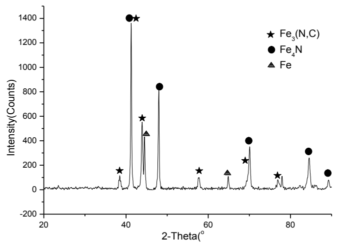

Figure 3 X-ray diffraction spectrum of carbonitrided surface layer of 4# samples

3.3 Test of hardness and thinkness of carbonitrided surface layer

Ladder hardness method is used to determine the thickness of carbonitrided layer. Setting the microhardness tester with loading 50g, holding for 15s. Hardness test will be processed every 30μm.

The carbonitriding layer thickness could be estimated by the hardness change value. The thickness of carburized layer, respectively as follows:1#：210μm；2#：180μm；3#：210μm；4#：150μm；5#：120μm. showed that the thickness of carburized layer for ductile cast iron was thicker than the gray cast iron, so, it can concluded that the effect of carbonitriding on ductile iron is more better.

Compared with the matrix metal, the hardness of the white layer and carbonitriding layer were improved significantly according to the microhardness value change with the depth from the surface. The surface hardness of ductile iron can be as high as 700-900 HV. The surface hardness of gray cast iron samples is 350-450 HV.

3.4 Wear resisitance analysis

The wear mass loss was used to represent the abrasion performance of the samples. The comparison of the wear loss between the carbonitriding treatment samples and the samples without carbonitriding shown in Fig 4. Compared to the samples without carbonitriding, the wear loss of carbonitrided was smaller. That is to say, ion carbonitriding can improve the wear resistance. This is because of that there are a lot of γ′(Fe_4N), ε(Fe_3N), Fe_3C phase distributed on the surface of carbonitrided samples which can improve the hardness of the samples, so it can enhance the wear resistance of the samples. In addition, the matrix metal is tempered sorbite which has excellent mechanical properties, with the high strength and toughness[2]. Compared to the carbonitrided grey cast iron samples, the wear loss of carbonitrided ductile cast iron samples is smaller. It instructionsed that after ion carbonitriding, the wear resistance of ductile iron is better than grey cast iron. The carbonitrided layer has high hardness after ion carbonitriding, and the abrasion performance improved to some extent.

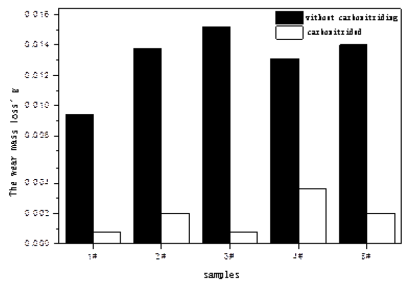

Figure 4 Wear lose of carbonitrided samples and the samples without carbonitriding

4.Conclusions

1) After ion carbonitriding, the hardness of matirix materials and surface improved greatly. The surface hardness of ductile cast iron layer can be as high as 700-900 HV. The surface hardness of grey cast iron is 350-450 HV.

2) After ion carbonitriding, there were bright layer and black diffusion layer appeared in the surface. The bright layer is the mixture of γ′(Fe_4N), ε(Fe_3N) and Fe_3C ,and it enhanced the surface properties of materials significant.

3)Compared with the samples without carbonitriding, the wear resistance of the ductile cast iron and grey cast iron can increased significant through the ion carbonitriding treatment. And it will enhance the fatigue and wear resistance, prolong its service life. Furthermore, the ductile cast iron shows more excellent wer resistance.

References

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