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Effects of nitriding and nitro-carburizing on the fatigue properties of ductile cast iron

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The effects of nitriding or nitro-carburizing treatments on rotating-bending fatigue properties were investigated on five kinds of pearlitic ductile cast iron samples. We produced containing of V, Al-Cr and Al-V alloyed ductile iron samples. Tensile and hardness characteristics of the nitro-carburizes samples compared to those of the nitrided ones and as-cast ductile irons without alloying element. The iron nitride formed on the surfaces of the nitride samples and the iron complex nitrides formed on the surfaces of the nitro-carburized ones. As a result, the fatigue lives existing in the higher stress range from 500 to 650 MPa was found to be longer in the order of as-cast, nitro-carburized and nitrided samples. However, the fatigue limit of the lower stress zone existing at 410 to 450 MPa and became no longer significant differences on endure limit by differences of nitiriding method.

Keywords: nitriding, nitro-carburizing, fatigue properties, ductile cast iron

1. Introduction

Nitrided ductile cast iron is used for precisely controlled components by oil pressure with complicated shapes for construction machineries because of not only its mechanical characteristics but also its superior machinability and castability. Recently, to changing green foundry, the pollution-free liquid nitro-carburization method (called Multinite) has been developed[1]

The nitriding process and the nitro-carburizing process are an industrial surface treatment process employed for the improvement of wear/friction and fatigue resistance of ductile cast irons, since it is associated with high production accuracy required in high precision controlled alloying elements. However, the fatigue properties of nitrided and nitro-carburized ductile cast iron with some alloying elements to control surface hardened layer are still under investigation. In this study, samples of pearlitic ductile cast iron (FCD700) with alloying elements such as Al, V and Cr were produced by nitriding and nitro-carburizing. These surface-improved ductile cast iron samples were observed by optical and EPMA elemental analysis and also done the rotating-bending fatigue test, to comparing and to optimize the chemical compositions for fatigue resistance.

2. Experimental Procedures

2.1 Materials

Ductile cast iron sample (FCD700) without alloying element is produced from high purity pig iron, mild steel, pure cupper, Fe-Si alloy and Fe-Mn alloy using a high frequency induction furnace. For the production of Cr 0.1%, V 0.1% and Al 0.1% samples, Fe-62%Cr alloy, Fe-83%V alloy and the pure aluminum are added individually at 1723 K in the same manner. The chemical composition of samples is shown in Table 1.

The gas nitriding processing was done in the industrial furnace used on the production site[2]. The nitrocarburizing processing was done in salt bath nitrocarburizing by the pollution-free liquid carburization furnace of 633K for holding time of 1.8ks and 833K for holding time of 18 ks.

2.2 Hardness test and tensile test

To investigate the hardness distribution from the surface of test piece, micro-Vickers hardness test was done at the load of 0.49 N. Tensile test was using Instron type universal testing machine, testing condition was crosshead speed of 8.3×10^{-3} mm/s and testing temperature was room temperature (R.T.).

2.3 Fatigue test

The fatigue testing was carried out using the test piece with 8mm diameter and the rotating-bending

Table 1 Chemical composition of samples (mass%).

Sample name		C	Si	Mn	Cu	Cr	V	Al
A	0.1%Al, 0.1%V	3.50	2.59	0.38	0.60	-	0.07	0.11
B	0.1%Al, 0.1%Cr	3.55	2.59	0.38	0.61	0.12	-	0.11
C	0.1%Al	3.53	2.48	0.37	0.60	-	-	0.10
D	0.1%V	3.57	2.63	0.39	0.60	-	0.08	-
FCD		3.39	2.68	0.37	0.58	-	-	-

fatigue testing machine, that testing condition the rotating speed of 3400 rpm and performed at R. T.

3. Results and discussion

Figure 1 shows the microstructure on near surfaces of nitride and nitro-carburizing samples. The matrix microstructure of all specimens are consists of pearlite matrix and ferrite structure around the spheroidal graphite. The white about 10μm thickness layer of specimen surface have observed which occurred from nitriding or nitro-carburizing heat treatment.

Table 2 shows the tensile strength and elongation of samples. These obtained values of surface-improved samples show lower value comparing to FCD 700 as cast condition. This reason considering that the heat affect to the sample surface by nitriding heat treatment, but occurred the hardened thin layer by nitriding or nitro-carburizing heat treatment.

Figure 2 shows the mapping of N distribution near surfaces of nitride and nitro-carburized samples. The nitrogen element was strongly distributed near the 10 μm from the specimen surfaces, considering forms complex nitrides. From the XRD analysis, the nitride layer consists of mainly nitrides of γ'-Fe_4N for nitriding samples, γ'-Fe_4N and ε-$Fe_{2-3}N$ for nitro-carburizing samples. The comparing to the thickness of the nitride layer and nitrogen diffusion depth of nitrided samples, the nitride layer of the nitriding sample seems more deeply nitrogen distribution comparing with nitro-carburizing one.

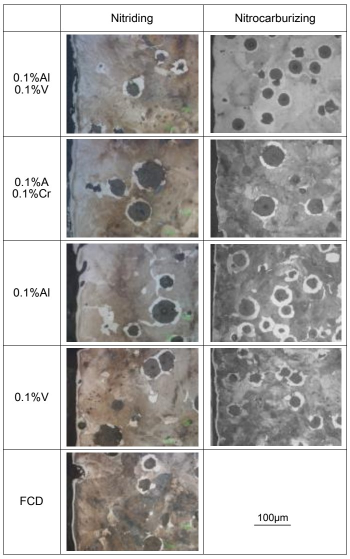

Fig. 1 Microstructure on near surfaces of samples.

Table 2 Tensile strength and elongation of samples.

	Sample name	Nitriding		Nitrocarburizing	
		Tensile strength [MPa]	Elongation [%]	Tensile strength [MPa]	Elongation [%]
A	0.1%Al, 0.1%V	620	1.1	656	2.3
B	0.1%Al, 0.1%Cr	650	1.2	692	2.4
C	0.1%Al	585	1.0	644	2.4
D	0.1%V	610	1.4	632	2.0

Figure 3 shows the S-N curves of as-cast, nitride and nitro-curburizied samples. The fatigue properties of nitride samples as indicated in outline marker shifted up to high stress side comparing to as-cast FCD700 sample as indicated double circle marker. The fatigue strength and endure limit of nitro-carburizied sample exhibits the intermediate region between nitrided sample and as cast sample.

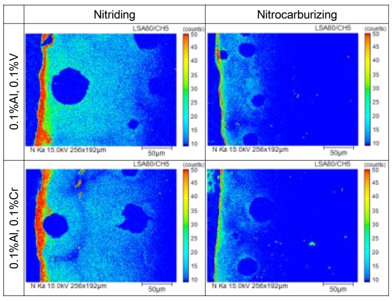

Fig. 2 Mapping of nitrogen distribution near surfaces of nitride and nitro-carburized samples.

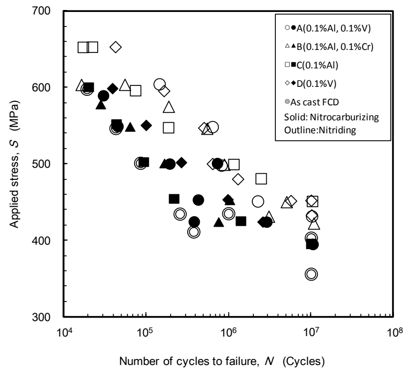

Fig. 3 S-N curves of as-cast, nitride and nitro-carburized samples.

4. Conclusions

1. The gas nitriding treatment is given to the ductile cast iron, the layer of γ'-Fe_4N is formed on the surface. And the nitro-carburizing treatment one is γ'-Fe_4N and ε-$Fe_{2-3}N$ phase formed.
2. The nitrogen element is diffused to matrix more deeply by using nitriding than nitro-carburizing heat treatment.
3. Fatigue property of nitride samples improves more effective than not only as-cast but also nitro-carburizing, because of owing larger width of hardened nitrides layer.

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