Research On The Properties Of Rotary Compressor Vane Coating

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Abstract

Compressor is developed to the direction of higher speed and load. As the vane of core component of the internal compressor assembly, the work condition is becoming worse. More attention is being attracted on surface treatment. Compressor vanes with surface treated by Nitriding Ni-P and DLC were selected to do the friction test and the impact on friction coefficient by duration, rate and load was also studied. Analysis on surface topography, chemical composition and bonding strength was performed by SEM and EDS, etc to investigate the different fractional behavior of relevant coating.

Keywords: vane、surface treatment、Ni-P、DLC、friction behavior

1. INTRODUCTION

There are many friction pairs in the internal of rotary compressor. The stress of the vane is complicated, the large plane of which has contacts with vane groove, while the small facet and R-plane has contacts with bearing and roller respectively. Heat and mechanical loss were generated when friction existed which increased the power consumption of the compressor. Lubrication and stress analysis can be used to improve the friction efficiency. Reducing the friction coefficient could be helpful to the improvement of the performance of compressor [1].

By the calculation of friction loss model, COP could be improved by 1.5% if friction coefficient can be reduced by 50% which showed that compressor property can be improved through reducing the mechanical loss.

Surface treatment is a technique method that formed a surface layer on the base matrix which has different mechanical, physical and chemical properties with original base material. Nitrogen treatment is always used to increase the surface hardness of the compressor vane. Surface treatment is a normal way to improve the corrosion resistance, wear resistance or some other specific functions. This essay analyzed the surface treatment compared with Ni-P and DLC treatment to investigate its friction behavior. Hitachi S-3400 Scanning Eletronic Microscope (SEM), HORIBA Energy Dispersive Spectrometer (EDS) and CETR-UMT3 friction tester are used to analyze the surface appearance, chemical component and friction behavior.

2. Coating performance

2.1、Surface appearance

Ni-P and DLC surface were observed and it’s shown that both surfaces are flat. Tiny processes were identified on Ni-P surface while certain micro crack existed on DLC surface, both of which were resulted from different forming process.

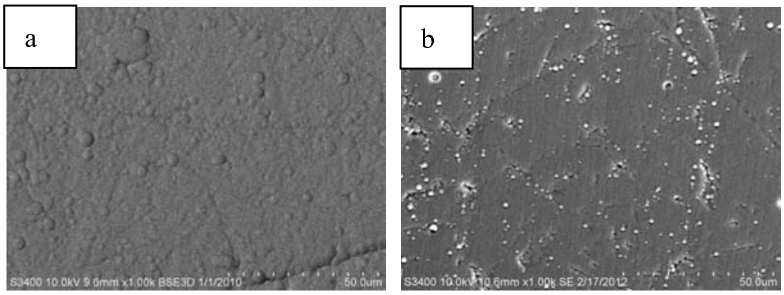


Figure 1. Surface appearance (a)Ni-P；(b)DLC

2.2、Indentation performance

Indentation performance of Ni-P was observed by microhardness tester and some fold were found at the edge, no cracks from center outwards were discovered which showed the good binding force of the coating with certain toughness. DLC has high hardness and fragility and cracks from center outwards were found.

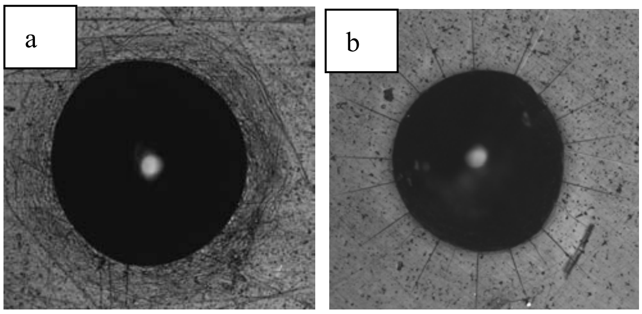


Figure 2. Indentation performance (a)Ni-P；(b)DLC

2.3、thickness observation

Thickness of both coating (Ni-P and DLC) were uniform through the observation of treated sample. The thickness of Ni-P coating was thicker, about 5μm while DLC was less than 3μm.

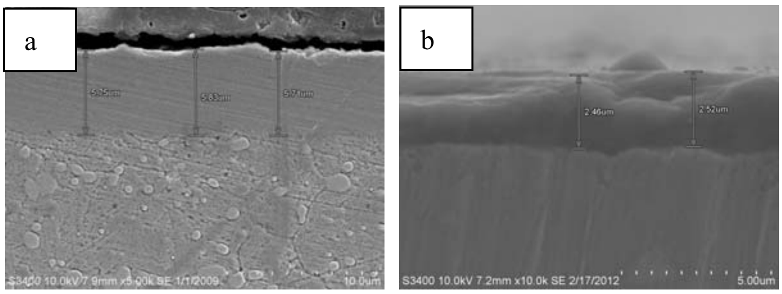


Figure 3. Profile appearance (a)Ni-P；(b)DLC

Result of energy spectrum showed that major component of Ni-P were Ni and P while that of DLC were C and Si.

Table 1. EDS result

	C	O	Si	Ni	P
Ni-P				96.44	3.56
DLC	92.85	6.35	0.80		

2.4、Scratch test

Diamond segment was selected to perform the test with radius of 0.8mm, scratch rate of 0.025 mm/sec, scratch length of 6mm and timing of 4 min. The critical load of different processing is as follows:

Table 2. The critical load of different processing

	DLC	Ni-P	Nitriding
Lc（N）	1.6-2.3	5.3-6.6	3.54-4.37

3. Friction test

With the consideration of accelerated test and actual force analysis, the condition is 50N-300N，150RPM-300RPM. The style of friction pair is as follows:

Figure 4. Friction tester

3.1、Impact of friction time on friction coefficiency

The trend of friction coefficient and friction loss with timing under the condition of 200N，300R/min were presented in the chart below. nitrided sample has highest friction coefficient while DLC the lowest. After 7h, friction coefficient of all the three samples was declined. With timing increased, friction loss were also increased.

Under the bad condition of 200N, 300RPM, the invalidation of Ni-P was faster and became close to the coating thickness in 1 h. In the following 7 h, friction loss was increased. DLC coating had almost no friction loss in the initial 1h but more than 2μm after 7 h.

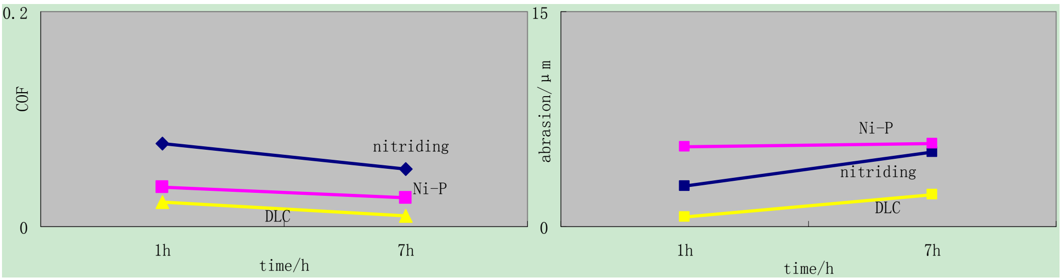
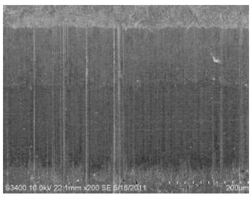


Figure 5. COF and abrasion VS time (200N, 300RPM)

As presented in the picture below, the width of the grinding crack of DLC vane is smallest while the Ni-P coating the largest and Ni-P coating had cracks at the bottom which might resulted the fast invalidation while DLC vane were worn out after 7 h friction.

	1 h	7 h
Nitriding		

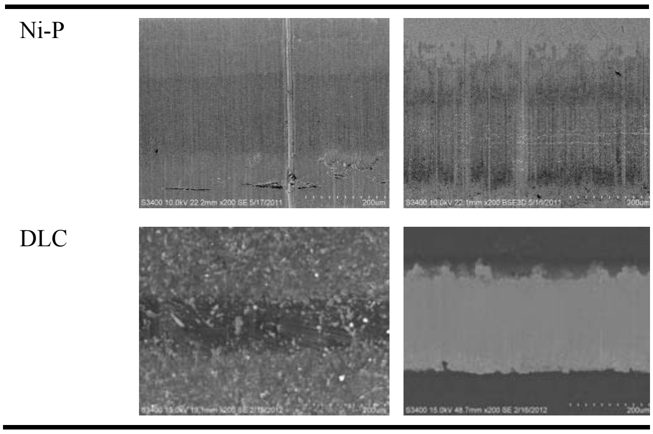


Figure 6. Comparison of grinding crack

3.2、Impact of rotational speed on friction coefficient

Under the condition of 200N (load), changes of friction coefficient and friction loss under the condition of different rotating rate（150rpm、200rpm、250rpm、300rpm）in 1h.

Nitrided vane had friction behavior with Ni-P coating under low rotational speed and friction coefficient increased sharply when the RPM was above 150. Ni-P coating maintained low friction coefficient but its friction loss was relatively large since friction coefficient is the average value in a period of time. The excellent friction behavior before worn out made the friction coefficient remained at a lower level. Both friction coefficient and friction loss of DLC vane can remain at lowest level.

Besides, friction loss increased with the decrease of rotational speed which may be resulted from different lubrication condition.

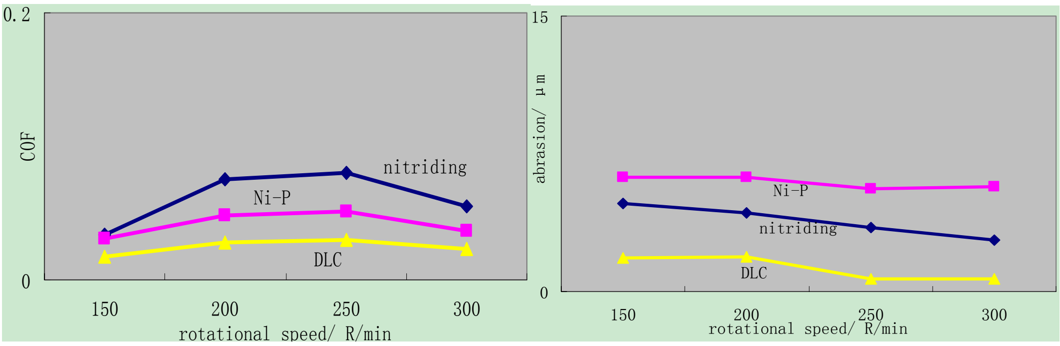
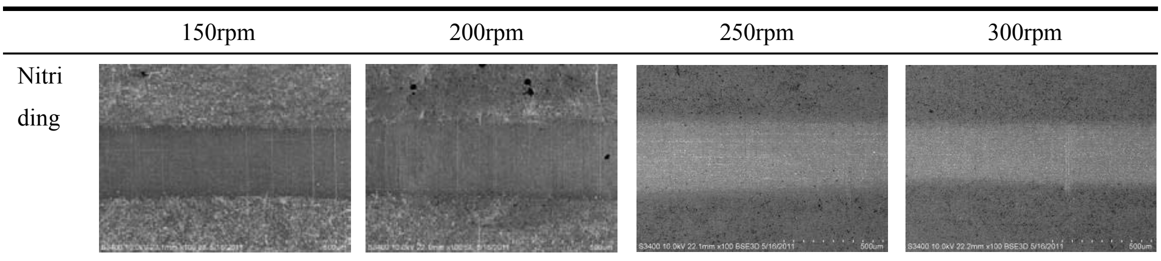


Figure 7. COF and abrasion VS time (200 N, 1 h)

From the observation of SEM, the width of grinding crack of nitrided vane is similar with Ni-P coating. But torn out track existed on the grinding crack of Ni-P coating which showed that under such condition, binding force of Ni-P coating is invalid. This might resulted the spalling of the whole coating instead of wearing out layer by layer. The grinding crack width of DLC vane is the narrowest with no worn out track.



Ni-P

DLC

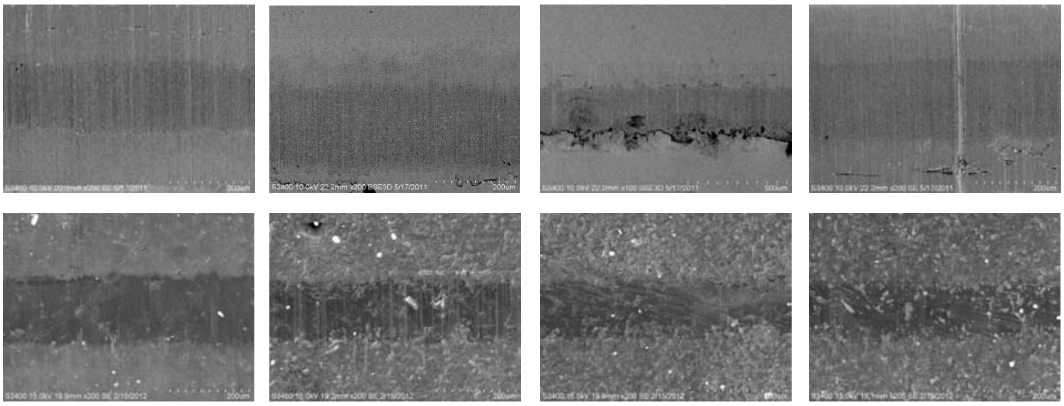


Figure 8. Comparison of grinding crack

3.3、Impact of loading on friction coefficient

Under the condition of rotational speed of 300 rpm, changes of friction coefficient and friction loss under the condition of different loading（50N、100N、200N、300N）in 1 h.

Under the condition of loading of 50N, Ni-P coating had similar friction coefficient with nitrided vane but Ni-P coating showed lower coefficient under the other three loadings. Friction loss increased with loading and Ni-P coating still had higher loss. The friction coefficient and friction loss remained extremely low but increased sharply under 300N.

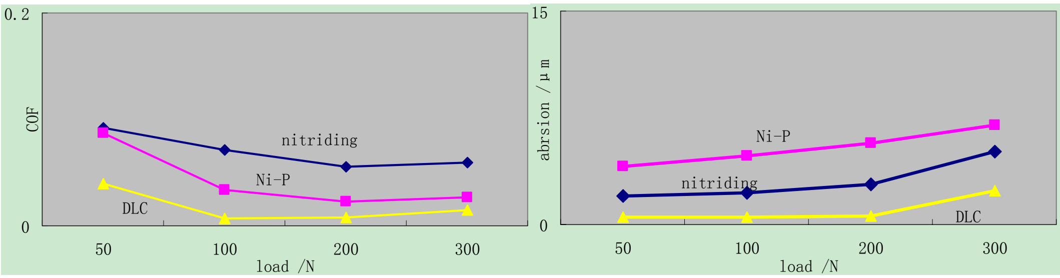


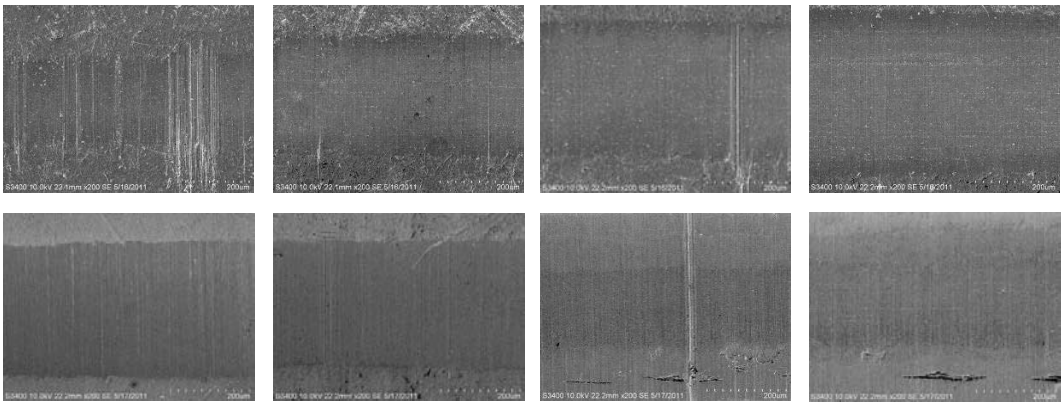
Figure 9. COF and abrasion VS time (300 RPM, 1 h)

From the observation of grinding crack, the width of grinding crack of Ni-P coating is larger. Torn out track existed on the wear track of the coating under all loading conditions except 50N and the crack became enlarged with the increase of load. It’s shown that binding force of Ni-P coating needed to be improved to meet the demand of high rotating speed and high load. When the load was over 200N, Ni-P coating had been torn out from appearance, basic material was exposed. The grinding crack width of DLC vane is very narrow under 300N and had good wear resistance property but would be torn out under the condition of above 300N.

50N 100N 200N 300N

Nitriding

Ni-P



DLC

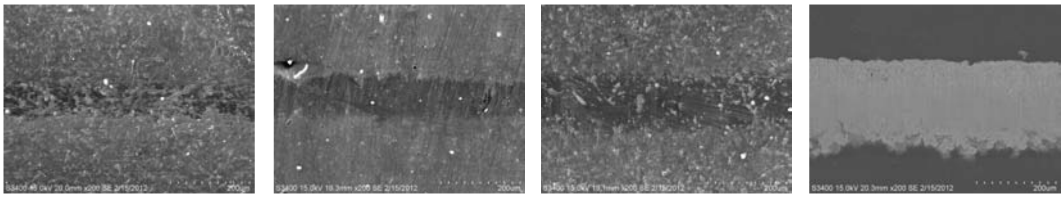


Figure 10. Comparison of grinding crack

4. Conclusion

(1) The surface of Ni-P coating and DLC coating were smooth and the component was uniform, with good binding strength with base body.

(2) Under the condition of 200N，300RPM, nitrided vane had highest friction coefficient while DLC the lowest. With the friction time increased to 7 h, friction coefficient of all the three surface treatment decreased and friction loss increased in which Ni-P the highest while DLC the lowest.

(3) Under the load of 200N, changing the rotational speed for 1 h, friction loss was higher when the rotational speed is lower which may be resulted from different lubrication condition. With the increase of rotational speed, friction coefficient was first increased and then decreased and the curve showed as an arch. Friction coefficient of nitrided vane was the highest, friction loss of Ni-P was largest and DLC vane could maintain a lowest coefficient and extremely low loss under various rotating ratio.

(4) Under the condition of 300RPM, changing the loading for 1h, Ni-P coating had similar friction coefficient with nitrided vane under lower loadings while better performance was observed under medium and high loading. Friction coefficient of DLC vane was lowest. Friction loss increased with loading increase. Loss of Ni-P coating was still higher and DLC vane almost had no friction loss below 300N but the loss was increased sharply when above 300N.

(5) From the observation of friction sample, the invalidation of Ni-P coating mainly resulted from the fast wearing out of coating after torn out but DLC could afford more worse conditions.

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