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Scuffing and Wear of the Vane/Roller Surfaces for Rotary Compressor Depending on Several Sliding Condition

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One of the serious challenges in developing rotary compressor with HFC refrigerant is the prediction of scuffing times and wear amounts between vane and roller surface. In this study, the tribological characteristics of sliding surfaces using roller-vane geometry of rotary compressor were investigated. The sliding tests were carried out under various sliding speeds, normal loads and surface roughness. During the tests, friction force, wear scar width, time to failure, surface temperature, and surface roughness were monitored. Because severe wear was occurred on vane surface, TiN coating was applied on sliding surfaces to prolong the wear-life of vane-roller interfaces. From the sliding tests, it was found that there was the optimum initial surface roughness to break in and to prolong the wear life of sliding surfaces. Depending on load and speed, the protective layers, which were composed of metallic oxide and organic compound, were formed on sliding surfaces. Those would play an important role in the amount of friction and wear between roller and vane surfaces.

Keywords : Alternative refrigerant, Vane-roller system, TiN coating, Rotary compressor

1. INTRODUCTION

Because of the ozone layer depletion issue, alternative refrigerants HFCs have been examined. In general, HCFCs or CFCs have better lubricity than HFCs. Since HFCs do not have chlorine atom, which react with iron surfaces to form ferrous chloride layers, lower extreme pressure is expected in HFCs. Thus, in order to develop the high efficiency and high reliable rotary compressors with HFCs refrigerants, the improvement in mechanical efficiency and wear resistance are becoming more important.

As the trend of the high speeds and loads was continued for the high efficiency and inverter of the compressor, the sliding condition of the surfaces was severe, such as shaft, bearing, and driving parts[1]. Therefore, the development of lubricating structure and the investigation of the material were required[2]. Also, many researchers exert themselves for the improvement of wear resistance in order to reduce frictional losses and secure the reliability in the bearing parts[3]. In rotary compressors, wear takes place mainly between vane and roller, shaft and bearing, roller and flange. Among these sliding pairs, the wear between vane and roller is the most critical.

In this study, the tribological characteristics of vane-on-roller geometry in the mixing environment of polyol ester(POE) and lubricant and R410A(HFC32/125, 50/50wt.%) refrigerant were evaluated.

2. EXPERIMENTAL DETAILS

2.1 TiN coating and vane surfaces

TiN coating for improving the tribological characteristics were selected and applied on vane surface. The wear characteristics of a coating can depend greatly on the deposition method. Because physical vapor deposition(PVD) can generally produce less distortion of the substrate and a finer surface finish, it was selected for this study. And TiN was deposited by arc ion plating as a manufacturing method. The thickness of TiN coating is 5 μm.

2.2 Test apparatus and test procedure

The vane-on-disk geometry was used in the sliding tester. The disks were cut out from the cylindrical bar of the roller material. The vane sample was also machined from the same type of vane material as is used in the real compressor in order to ensure the mechanical properties. The TiN coating was applied only on the vane surface. The vane material was made of SKH51 and had hardness in the range of 850~900Hv. The roller material was made of Ni-Co-Mo gray cast iron and had hardness in the range of 550~600Hv. The surface roughness of the disk was grounded to 0.14 μm Ra, which is close to the original roughness of the roller.

The sliding tests were carried out repeated pass sliding using a vane-on-disk type tribometer under the various normal loads and sliding speeds in R410A/POE mixed environment. This tribometer was capable of measuring the frictional forces and normal forces. And this tester has the pressure vessel which is able to apply pressure of 20 bars. Test pressure of 3 bars was applied and test temperature was set at 50℃ initially. The vane was located in a holder that was clamped to a fixed arm with a transducer for friction force. The lower flat disk(roller material) was mounted on a rotating shaft in the oil bath. The contact was achieved by pressing the vane against the flat surface under a normal load applied by a spring force, which reduced the variation of normal force during sliding.

And, step load tests were performed in R410A/POE mixed environment. The initial load was 40kg and it was increased by 20kg every 5min to severe wear or scuffing. After each step load test, the surface roughness of vane tip was measured with a surface profilometer, and wear scar width was examined using an optical microscope.

3.RESULTS AND DISCUSSION

3.1 Wear amount and wear rate under the normal

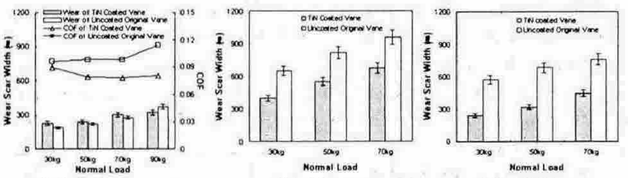
loads and sliding speeds

The wear scar widths for various normal loads and sliding speeds are shown in Fig. 1. The wear amount was lower for TiN coated vane than uncoated original vane because wear resistance of the vane was improved by TiN coating. As shown in Fig. 1a, the wear amount of TiN coated vane was a few higher in ranges of 30~70kg. But at 90kg, wear of uncoated original vane was increased, accompanied by rapid increasing of friction force. Besides, the wear amount of the vane was increased with increasing normal load. Also, as the sliding speed increased, the wear amount of the vane increased. But at 1000rpm, the wear amount decreased. That is reason that the lubrication regime shifted from the boundary lubrication to the mixed lubrication.

Wear rate K was calculated from the wear amounts. Fig. 2 shows the wear rate K of TiN coated vane and original vane for the various sliding speeds. At all speeds, the wear rate of TiN coated vane was lower than that of original vane. Therefore, the wear resistance of the coated vane is better than that of the original vane.

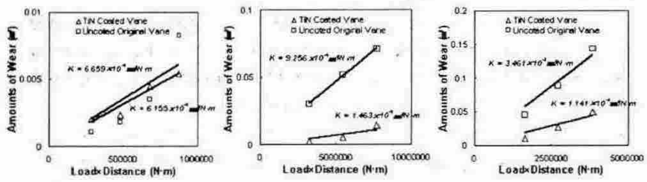
3.2 SEM and EDS analysis of TiN-worn surfaces

Fig. 3a is SEM picture of TiN coated vane tip after the sliding test at 500rpm for 2 hours. Three parts, which were TiN coating, vane substrate, and worn TiN, appeared on the vane tip. TiN coating was the untouched part that maintained initial surface without contact. Vane substrate was the totally worn part that exposed the substrate. And worn TiN is the only TiN-worn part. Also, Fig. 3b and 3c are EDS analysis for TiN coated vane tip before and after sliding. As shown in the figure, Ti component before sliding cannot be observed after sliding.



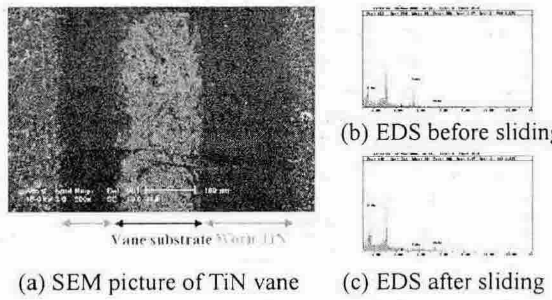
(a) 100rpm (b) 500rpm (c) 1000rpm

Fig. 1 Wear scar width of the vane tip under various normal loads and sliding speeds



(a) 100rpm (b) 500rpm (c) 1000rpm

Fig. 2 Wear coefficient K of the vane at each sliding speeds



(a) SEM picture of TiN vane (b) EDS before sliding (c) EDS after sliding

Fig. 3 SEM and EDS analysis of TiN coated vane tip

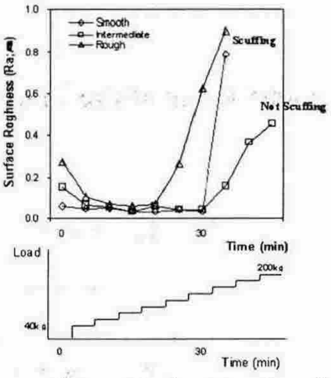


Fig. 4 Time to scuffing and changes of surface roughness depending on the initial surface roughness

3.3 Time to scuffing and changes in surface roughness

Time to scuffing depending on the initial surface roughness was evaluated and the changes in surface roughness of TiN coated vane were observed with three different surface roughness. The results of changes of surface roughness are shown in Fig. 4. Loads were increased in steps as seen in lower part of the figure. Smoothing first occurred for the original rough and intermediate surfaces. All surfaces had the same roughness after about twenty minutes of sliding. After that, as the load increased the surfaces became rougher for all cases. These test series were ended when severe roughening occurred. The surfaces with original intermediate roughness roughened more slowly than did those with the rougher and smoother surfaces. And, time to scuffing of this surface was longer than that of smooth and rough surface. Thus, there was the optimum initial surface roughness to break in and to prolong the wear life of the vane-on-roller sliding surface.

4. CONCLUSION

In order to improve the wear resistance of a rotary compressor TiN coating was applied on the vane surface, and the tribological characteristics of sliding surface using roller-vane geometry were evaluated under the R410A/POE mixed environment. These results suggest the following conclusions.

(1) The TiN coating for the vane surface improves the wear resistance, compared with uncoated original vane in roller-vane geometry.

(2) As the normal load increased in the vane-on-disk, the wear amount increased. As the sliding speed increased, the amount of wear of the vane increased. But at 1000rpm, the wear amount decreased.

(3) From the sliding tests of coated vanes having three different surface roughness, it was found that there was the optimum initial surface roughness which improve the load carrying capacity and prolong the wear life of sliding surfaces.

5. REFERENCES

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