TRIBOLOGICAL CHARACTERISTICS OF COATED VANE SURFACES UNDER MIXED ENVIRONMENTS OF VARIOUS OILS AND CO2 AS A REFRIGERANT

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ABSTRACT

The CO2 is investigated as an alternative refrigerant to replace HFC refrigerant in air conditioning systems due to the environmental concerns. Because new compressors with CO2 are going to be operated under the high pressure, the tribology of sliding surfaces in the compressor becomes very important. To develop new compressor, especially rotary type, the friction and wear characteristics of sliding surfaces between a vane and a roller in the rotary compressor were evaluated in this paper. Several hard coatings, such as TiN, CrN, WC/C and two types of nitridings, were applied on vane surfaces in order to improve the tribological characteristics, and their performances were evaluated experimentally. Two types of lubricants were used, namely POE (polyol ester) oil and PAG (polyalkylene glycol) oil. The vane-on-disk type sliding tests were performed with an exclusive high pressure wear tester. From the tests, coefficient of friction and wear volume of vane surfaces applied various coatings were compared. Test results showed that WC/C coatings showed good tribological properties. TiN and CrN coated vanes showed good wear resistance properties but produced high friction. Also, the results of the sliding tests showed that using PAG oil has an advantage over POE oil in CO2 environment.

1. INTRODUCTION

For the last few decades it has been realized that CFC (chlorofluorocarbon) and HCFC (hydrochlorofluorocarbon) refrigerants cause the ozone depletion, so the use of CFC refrigerants were prohibited and HCFC refrigerants will be phased out by 2020 according to the Montreal Protocol. Therefore, several alternative refrigerants, namely HFCs (hydrofluorocarbons), have been proposed for replacing HCFCs. However, HFCs contribute to the greenhouse effect because their global warming potential (GWP) is extremely high. The global warming potential is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming and an index that relates the potency of a greenhouse gas to the carbon dioxide (CO2) emission over a 100-year period. The GWPs of the HFCs are in the order of 1300–1900 as compared with CO2 whose GWP is one. The production of HFCs may thus be completely forbidden in the near future as it was restrained in the Kyoto Protocol signed in 1997. Therefore, the researches of alternative refrigerants were focused on natural refrigerants, which have low GWP.

Natural substances, such as water, ammonia, nitrogen and carbon dioxide, are not the artificial compound and cause no harm to the global environment, so their application as refrigerants is positively investigated [1]. Among natural refrigerants, carbon dioxide has lately attracted considerable attention. CO2 is an excellent refrigerant because it is nontoxic, nonflammable, and inexpensive. Also, it does not have to be withdrawn. However, the shell of refrigerating system must be made of resisting pressure materials because the saturation pressure of CO2 is high. If CO2 was applied to the compressor and refrigeration system as a refrigerant, not only resisting pressure design of entire system but specially strength analysis, lubrication analysis must be reconsidered [2].

Rolling-piston type rotary compressors are widely used in air conditioners and refrigerators. In the rolling piston rotary compressors, wear takes place mainly between vane and roller, vane and cylinder slot, roller and cylinder. Among these sliding pairs, the wear between vane and roller is the most critical [3].

In this study, the effect of various surface coatings was evaluated on tribological characteristics of vane-on-roller surfaces of a rotary compressor under mixing environment of CO2 refrigerant and POE and PAG oils which are being considered as new refrigeration lubricants because of their good lubricity and good miscibility with carbon dioxide.

2. SURFACE COATINGS ON THE VANE SURFACES

Several hard coatings with potential for improving the tribological characteristics were applied on the vane surface, such as TiN, CrN, WC/C (tungsten carbide carbon) and two types of nitridings treated on 460°C and 480°C.
3. RESULTS

Fig. 1 shows the wear scar widths for various coated vanes at 300 N and 2000 rpm in CO2/POE and CO2/PAG mixed environment. Wear of the uncoated original vane was largest. All coated vanes showed 1/2 or 3/4 as much wear as the uncoated original vane. The amount of wear of the coatings was the least for CrN, somewhat greater WC/C, and the highest for salt bath nitriding treated on 460°C. Also, wear in CO2/PAG environment was smaller than that in CO2/POE environment. The amount of CO2 refrigerant dissolved in oil of the same volume was larger in POE oil than that in PAG oil. This is because the viscosity of oil dropped as the amount of refrigerant increased.

The worn surfaces of all vane tips were observed with SEM. Fig. 2 shows SEM images of wear scars for each coated vane after sliding tests in CO2/POE mixed environment. The worn surface of the original vane tip showed the extensive plastic deformation, along with the deep and with scratched, as shown in Fig. 6a. The worn surfaces of CrN and WC/C coated vane tips typically were smoother than the initial surfaces. And pits were observed in the worn surface of the CrN coated vane. The plastic deformation and many scratches were observed for the worn surfaces of nitriding vane tips, such as that of the uncoated original vane tip. And the worn surface of TiN coated vane was very smooth.

In pure POE and PAG oils environments without CO2 refrigerant, wear of all coated vanes was evaluated at 300 N and 2000 rpm. Wear scar widths of all coated vanes are shown in Fig. 3. In comparison with Fig. 1, the amount of wear for all vanes was more reduced in only oil environment than in CO2/Oil mixed environments. Wear for each coating showed trends similar to those tested in a refrigerant/oil environment. Wear of all vanes increased when the carbon dioxide was dissolve in oil. Particularly, wear of the uncoated original vane was higher in CO2/POE and CO2/PAG mixed environments than in only POE and PAG oils. Consequently, all coated vanes tested are superior to the uncoated vane in the compressor environment that the refrigerant is dissolved in oil. And, wear in only PAG environment was similar to that in only POE environment.

4. CONCLUSION

Wear in only PAG oil environment was similar to that in only POE oil. But using PAG oil has an advantage over POE oil in the carbon dioxide environment. The amount of wear of the vanes increased rapidly when the carbon dioxide was dissolved in oil. This is because the viscosity of the oil dropped as the carbon dioxide was dissolved in oil. The nitriding treatment on the vane surface was not suitable because it wear quickly and its friction were very unstable. The CrN and TiN coated vanes showed good wear resistance. However, they produced high friction. The WC/C coating showed the best tribological performances among the coatings tested.

5. REFERENCES