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Research Article

WEAR TESTS OF SLIDING SURFACES IN THE ENVIRONMENT OF MIXTURES OF LUBRICATING OILS AND REFRIGERANTS

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ABSTRACT
Elements of refrigeration compressors may be exposed to various types of wear processes, depending on the used oils and refrigerants. The presence of the refrigerant makes the lubricating properties and anti-oil mixture - factor much worse than in case of the lack of refrigerant oil. Current regulations on the use of ODS phase-out of working require refrigeration synthetic refrigerants HCFC (e.g. popular R22). The paper presents the effect of different mixtures of oils and refrigerants on friction coefficient and surface condition of cast iron and aluminium PA6. Tests were performed on a prototype machine using frictional node type block-on-ring, which is located inside a pressure chamber that simulates the refrigeration compressor. The results of the study confirm the possibility of using green refrigerant R290 (propane) as a substitute for R22, while keeping the existing mineral oil.

Keywords: refrigerant, refrigerating oil, the coefficient of friction.

INTRODUCTION

At the beginning of the XX century, compounds of chlorine, bromine, iodine and fluorine with carbon as refrigerants came into use. At the time, the substances, due to better thermodynamic properties, superseded such refrigerants as: ammonia, chloromethane, sulphur dioxide, propane and isobutane. Over 80 simple compounds which could be refrigerants were selected; among them were the following long time applied initiators R11, R12, R13 and R22. Only in 1974, the hypothesis by S. Rolanda and M. Moliny [10] on the emission harmfulness of the compounds destroying ozone in atmosphere, stopped their development. At present, tendencies concerning the application of the refrigerants are forced by respective regulations [11, 12]. On one side, they look for more ecological synthetic refrigerants and, on the other hand, there is a return to natural initiators (carbon dioxide, ammonia, hydrocarbons).

Changes of applied refrigerants usually require the design of refrigerating appliances to be adapted and lubricating oil to be changed. The refrigerant and lubricating oil create a mixture in friction nodes of refrigerating compressors. Complex mixture dependencies cause sooner compressors wear [1, 3].

The review of scientific literature on tribological investigations concerning the model friction nodes of refrigerating compressors showed that the majority of tests were performed on the prototype test stands [2, 9, 10, 11, 13]. No published work described a node type friction block-on-ring with the surface-contacting mating surfaces. According to the tests carried out by authors on real compressors wear, this node type is the most representative one for the operation of the radial slide bearings. The above mentioned test gap became an excuse to make the own elaboration, as well as the stand for wear tests of sliding friction nodes of refrigerating compressors in the environment of mixtures of lubricating oils and refrigerants. Using the elaborated method and test stand, tests are made to compar two kinds of lubricating oils in the mixture with natural refrigerant, such as propane R290. Literature gives little information on the influence of refrigerant R290 on the sliding surfaces of the refrigerating compressors. This paper presents also the tests carried out with the use of the refrigerant R22 being at present withdrawn from the refrigerating mechanisms.

TEST METHODS

In order to determine tribological properties of the mixtures of refrigerant and lubricating oil in the laboratory conditions, we made a prototype stand with the friction node type block-on-ring (Figure 1) situated in the high-pressure chamber (Figure 2).

The test stand, first of all, enables to present the operation conditions of the refrigerating compressors (compound temperature, refrigerant pressure, friction node loading, roller rotational speed), lubricating oil and refrigerant mixture production and the wear process occurrence in the conditions of the refrigerating compressors operation. The measuring position software enables to illustrate and register values such as the moment of friction, rotational speed, mixture temperature and refrigerant pressure in the chamber. The roller rotational speed is controlled with a frequency converter. The speed value can be set automatically or manually within the range 0 to 3000 rpm. The load value is set by the operator through weights within 10 to 150 N and changed of the minimum value 5 N.

The stand allows for the friction moment measurement within the range from 0 to 2 Nm. The operator can determine test duration and the frequency of the measurement registration. With the use of the thermostat connected with heaters located in the chamber, the temperature of the mixture of lubricating oil and refrigerant can be controlled.

The test stand with the friction node type block-on-ring is equipped with a high-pressure chamber with the sealing system preventing air entrance inside. The chamber enables obtaining conditions similar to vacuum ones as well as maximum refrigerant pressure of the value order 0.8 MPa. Sealing is very important due to high pressure occurring when the mixture is saturated with the refrigerant and the drive shaft output out-

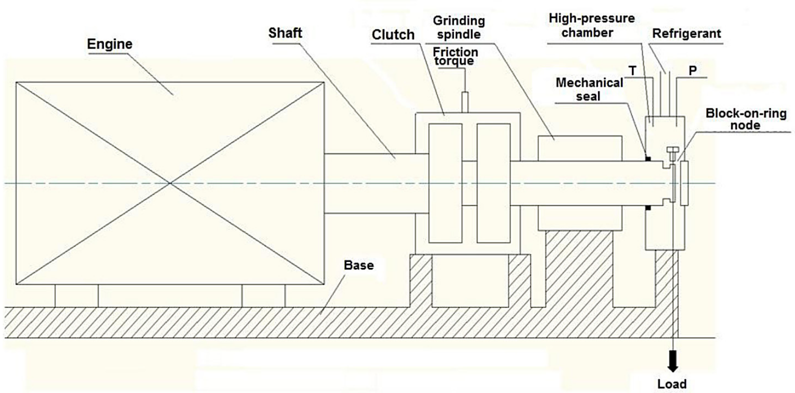

Fig. 1. Schematic tribometer test material consumption of refrigeration compressors. T – temperature in the chamber, P – measuring the pressure in the chamber, Mt – friction torque measurement

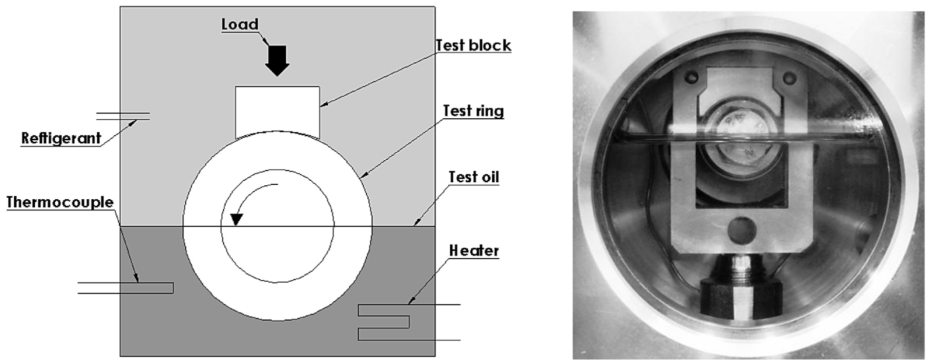

Fig. 2. Node type friction block-on-ring, a) schematic model of the chamber position, b) the chamber model with the actual node

side the chamber. All places susceptible to leakage are checked whenever the tested mixture is made.

Before starting the tests, all the elements contacting the latter mixture (the samples, handles and inside the high-pressure chamber) were thoroughly cleaned with naphtha extraction, and in case of samples an ultrasonic washer was used. After mounting the sample and counter-sample in the handles situated in the chamber and after closing it tightly, the vacuum ranging 10^{-5}MPa was made inside. Then, lubricated oil was poured into the chamber to the height covering half of the roller diameter (Figure 2). The mixture of lubricating oil with refrigerant was made according to the recommendations of Hong-Gyu [5] and Hoon Choa Sung [6], i.e. the high-pressure chamber was filled three times with refrigerant under pressure of 0.5 MPa and left there for 20 h for the right saturation of lubricating oil with refrigerant and in order to achieve a steady state. The tests were performed in the temperature of the beginning of the test at 298±1 K corresponding the starting conditions of the refrigerating compressors. During the test, pressure and temperature of the tested mixture were registered.

For the test, we used immobile concave block-shaped samples of aluminium PA6 (AlCu4MgSi) and rotating roller-shaped counter-samples of grey cast iron GJL-200. The tests were carried out at the load of 120 N thus achieving the block specific force on the roller being 1.155 MPa. The tests were performed for 3600 s at the roller rotational speed being 500 rpm. The friction path was 188.5 m.

The model friction node was tested in the environment of chosen mixtures of lubricating oils and refrigerants. They made tests with the use of the refrigerant R22, being now withdrawn, mixed with mineral oil and the refrigerant R290 in mixtures with mineral oil (MO) as well as with synthetic oil based on polyester (POE). The table 1 presents the most important properties of the tested refrigerants whereas the Table 2 gives the characteristics of the tested lubricating oils.

RESULTS AND DISCUSSION

Friction coefficient

The test stand computer system registered the friction moment values in the individual tests enabling the determination of the friction coefficient average values, of some mileages, in time. The Figure 3 presents average curves of the friction coefficient mileage for the tests of the mixture: lubricating oil RENISO KM 32 (MO) with the refrigerant R290, lubricating oil PLANETELF ACD 32 (POE) with refrigerant R290, and lubricating oil RENISO KM 32 (MO) with the refrigerant R22.

The friction coefficient had different values in the moment of the engine start and then after about 1500s it stabilized. In the tests carried out with the mixture R290/POE the friction coeffi-

Table 1. Basic properties of the tested refrigerants [4]

Property	Unit	Refrigerant	
		R22	R290
Chemical formula	–	CHF_2Cl	$CH_3CH_2 CH_3$
Critical point	K	369.3	369.8
Critical pressure	MPa	4.99	4.28
Critical specific volume	m^3/kg	0.0019	0.004531
Ozone layer destruction potential ODP	–	0.055	0
Greenhouse effect creation potential GWP	–	1700	3

Table 2. Basic characteristics of lubricating oils studied [7, 8]

Parameter	Unit	Lubricating oil	
		Reniso KM 32 (MO)	Planetelf ACD 32 (POE)
Kinematic viscosity in the temp. 313 K in the temp. 373 K	m^2/s	$32 \cdot 10^{-6}$ $4.9 \cdot 10^{-6}$	$34.6 \cdot 10^{-6}$ $6.0 \cdot 10^{-6}$
Flow temperature	K	228.1	219.1
Flash-point	K	475.1	523.1
Density (in 288 K)	kg/m^3	881	981

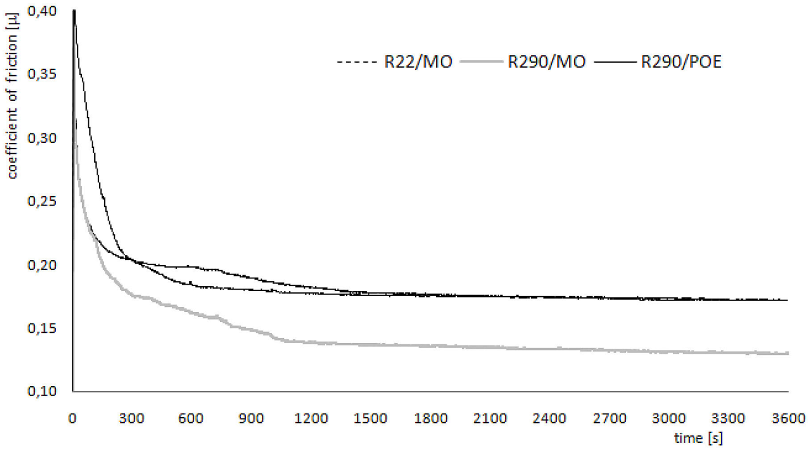

Fig. 3. Mileage coefficient of friction during the test for mixtures: lubricating oil RENISO KM 32 (MO) with refrigerants R290, lubricating oil RENISO KM 32 (MO) with refrigerants R22 and lubricating oil PLANETELF ACD 32 (POE) with refrigerants R290

cient was 0.137 whereas in case of the mixtures R290/MO and R22/MO it was 0.174. Such friction coefficient values suggest the grounds of substituting less ecological refrigerant R22 with R290 for the node friction wear criterion in the refrigerating compressors. In turn, one can state that when changing the refrigerant from R22 to R290, from the point of view of tribology, it is not necessary to change lubricating oil. However, at the occasion of changing refrigerant the change of lubricating oil should be taken into account individually when analysing the operation conditions of individual element of the refrigerating system.

Surface of friction

The friction nodes surfaces, i.e. roller and block surfaces were subjected to observation with the use of the metallographic microscope CARL ZEISS JENA. In case of block surface observation was made at enlargement ×63 and ×126. However, the roller observation was made at enlargement ×63, ×125, ×252 and ×504. The figure 4 presents the comparison of the new surface with the surfaces of the mating elements (grey cast iron / PA6) in the mixtures: R290/MO, R290/POE and R22/MO.

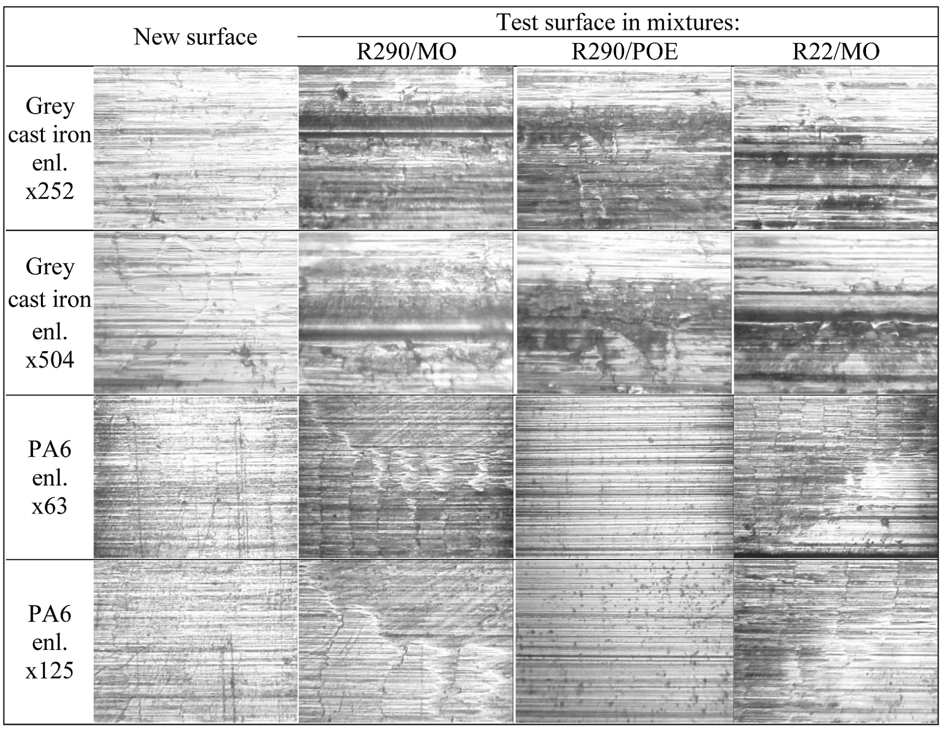

Fig. 4. Comparison of new surface after the test surfaces in a mixture R290/MO, R290/POE and R22/MO

Surfaces after tests with refrigerants are not equal. One can specially notice heterogeneity on all grey cast iron surfaces and on aluminium PA6 surface after tests with the use of mineral oil.

On the grey cast iron surfaces being in contact with mineral oil, researchers noticed traces of grooving in the presence of refrigerant R290 as well as R22. However, they were not noticed on the surfaces operating in the mixture of refrigerant R290 with oil POE.

Watching the surface after testing in the mixtures of refrigerant with oils for refrigerating compressors, the presence of deposits on the friction surfaces was found. The dark deposit layer occurred mainly on the surface of aluminium (PA6), except for the surface after testing in the mixture R290 with oil POE. This surface is relatively homogeneous. There are many shallow, uniform grooves suggesting homogeneous, slow surface wear without wear products (abrasive or deposit).

CONCLUSIONS

We noticed about 20% decrease of the friction coefficient between grey cast iron and aluminium in the mixture of propane with oil POE in comparison with mineral oil. However, the change of refrigerant only, R22 to R290 did not influence the change of friction coefficient. On the friction surfaces we observed the occurrence of deposits, except for aluminium surfaces contacting the mixture of refrigerant R290 with oil POE. Probably, the lack of deposits on the surface caused a significant decrease of friction coefficient.

At present, due to valid regulations concerning the application of substances impoverishing the ozone layer, there is the exchange of refrigerant R22 from the refrigerating systems to other alternative refrigerant. The performed tribological tests confirm that the interchangeable equivalent of refrigerant R22 can be the ecological one R290 (propane). Leaving mineral oil in the installation will not deteriorate tribological properties of the resultant mixture. However, additional exchange of mineral oil from the installation to oil POE will improve tribological properties of the new mixture, in comparison to the mixture of propane with mineral oil.

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