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CHARACTERISTICS OF STANDS FOR WEAR TESTS OF MATERIALS FOR REFRIGERATION COMPRESSORS ELEMENTS

CHARAKTERYSTYKA STANOWISK DO BADAŃ ZUŻYCIOWYCH MATERIAŁÓW NA ELEMENTY SPRĘŻAREK CHŁODNICZYCH

Key words:

refrigerant compressors, compressor oils, friction and wear, testing device

Słowa kluczowe:

sprężarki chłodnicze, oleje sprężarkowe, tarcie i zużywanie, stanowiska testowe

Summary

A desirable feature of oil lubricating refrigeration compressors is its solubility in refrigerant in the full range of working temperatures. It en-

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ables the majority of oil "pumped out" to the refrigeration circuit to return to the lubrication system. However, oil separated from the refrigerant and introduced to the lubrication system contains a certain amount of the refrigerant, so we can state that the compressor elements are lubricated with the mixture of oil and refrigerant of properties being surely worse than the ones of pure lubricating oils.

In the days of changing old refrigerants to the new ones, being more environmentally friendly, it is very important to use them with the proper compressor oils. Apart from the mentioned requirement of "solubility," it is also necessary to ensure the right anti-friction and anti-wear properties (concerning "oil–refrigerant" mixtures). That is why the paper analyses literature information on test stands, enabling us to make a quantitative evaluation of this problem, and there are formulated assumptions for the construction of our own universal testing device.

INTRODUCTION

The Montreal Protocol signed in 1987 and introduced in use in 1989 demanded the elimination of refrigerants of the CFC group according to the determined schedule and on longer period also the HCFC refrigerant in order to protect the ozone layer. In Poland the above directive is realised by the act concerning substance reducing the ozone layer **[L. 1]**, determining among others, the date to which the application of the determined refrigerant is allowed. The refrigerant of the HCFC group (e.g. R22) can be applied only till the end of 2009, whereas the restored and regenerated refrigerant of this group can be applied till the end of 2014 unless the European Committee shortens the term **[L. 2]**. At present, the refrigerant being safe for the environment are introduced and they substitute the ones being withdrawn from the market.

There are some basic requirements concerning oils applied in refrigeration systems (lubrication, cooling) but also many others at different parameters of the refrigeration installation. The basic problem is the application of oil being solidification resistant in low temperatures occurring in the evaporator. Oils must be oxidation resistant and cannot cause carbon deposit and sludge collection. Besides, they should characterize with proper purity and small acid value. Further, oil miscibility with the refrigerant should be checked as well as oils compatibility with refrigerants. Moreover, oils must have the right lubricating properties ensuring the creation of an oil film on friction elements as well as the ability to return from the refrigeration system to the compressor. Oil should also have certain hygroscopicity due to the possibility of water appearance in the system **[L. 3]**.

Now, there are many new refrigerants on the market. Apart from proper thermodynamic properties they should also characterise with the following features: chemical inertnesss in relation to lubricating oils and construction materials in the device, ability to dissolve a small amount of water, zero value of ozone destroying potential (ODP), possible low potential of the greenhouse effect creation GWP (Global Warning Potential referred to carbon dioxide GWP = 1) and a very important property, namely the refrigerant should be able to create a mixture with lubricating oil.

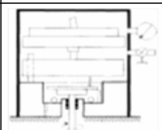
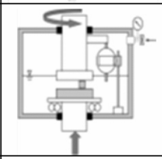
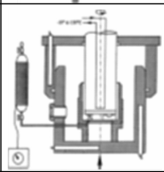
TRIBOLOGICAL STAND TESTS OF REFRIGERATION COMPRESSORS MOVING PAIRS

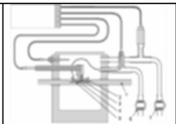
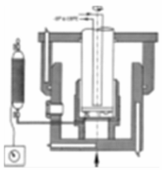
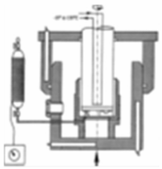
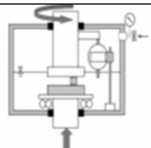
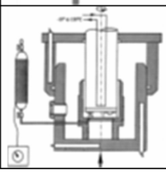
The list of literature contains works in which they analyse the elements wear in the atmosphere of the refrigerant in the presence of lubricating oil **[L. 4–16]**. The authors use various test stands. During the tests, they usually use the tribological system of the pin-on-disc type. All the devices are situated in special chambers ensuring the influence of the refrigerant and oil on the moving elements wear. The friction pairs can be subjected to the right pressures and speeds. The refrigerant pressure and temperature in the chamber can be controlled (**Table 1**).

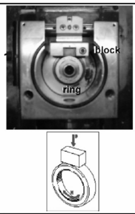
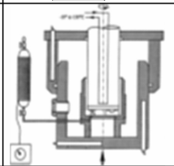
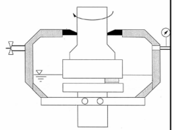
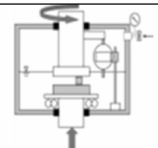
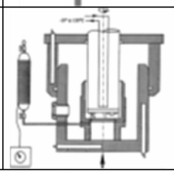
The **Table 1** contains the collection of the most important information on the valid stand tests concerning elements of the refrigeration compressors operating in the atmosphere of the oil and refrigerant mixture. The table presents: measurement stand, kind of motion occurring on the stand, testing environment (oil, refrigerant), materials of the friction pair, measurement parameters (pressure, temperature, speed, time), measured values and methods applied to determine them. In order to determine the wear mechanisms in the refrigeration compressors they usually used the following auxiliary measurements: electron scanning microscopy (SEM), Aguer's electron spectroscopy (AES), X-ray spectroscopy (EDX), X-ray photoelectron spectroscopy (XPS). These methods enable the determination of the chemical constitution of worn surfaces and wear products.

Table 1. Summary of valid tests concerning durability of refrigeration compressors elements: MO – mineral oil, AB – alkylbenzene oil, PAO – polyalphaolefines oil, PAG – oil basing on polyalkylglycols, POE – ester oil, PTFE – polytetherfluorethylene, PEEK – polyetheretherketone, GZ – wear depth ST – friction force, WT – friction coefficient, SEM – electron scanning microscopy, AES – Aguer's electron spectroscopy, EDX – X-ray spectroscopy, XPS – X-ray photoelectron spectroscopy, PP – surface profile measurement, SZO – chemical constitution of worn surfaces and wear products

Tabela 1. Podsumowanie aktualnych badań dotyczących trwałości elementów sprężarek chłodniczych: MO – olej mineralny, AB – olej alkilobenzenowy, PAO – olej polialfaolefinowy, PAG – olej na bazie polialkiloglikoli, POE – olej estrowy, PTFE – politetrafluoroetylen, PEEK – polieteroeteroketon, GZ – głębokość zużycia, ST – siła tarcia, WT – współczynnik tarcia, SEM – elektronowa mikroskopia skaningowa, AES – spektroskopia elektronów Aguera, EDX – spektroskopia rentgenowska, XPS – rentgenowska spektroskopia fotoelektronów, PP – profilometria powierzchni, SZO – skład chemiczny zużytych powierzchni i produktów zużycia

Kind of motion	Stand scheme	Source	Refri-gerant	Compre-ssor oil	Construction materials	Measuring parameters					Measu-red values	Auxiliary methods	
						Pressu-re [MPa]	Tempe-rature [C]	Power [N]	Speed [m/s]	Time [s]		Measu-ring method	Purpose of measure-ment
rotation and pulsation		[4]	R134a	MO AB PAO PAG POE	Steel/steel	3.58 6.792 10.8	70	45	0.94		GZ ST WT	SEM	PP
rotation and pulsation		[5]	CO_2	PAG POE	Grey cast iron/ tool steel	0.5 1 1.5		500	0.725 1.425 2.85	7200	GZ WT	AES SEM Vickers'	SZO PP Hardness
rotation and pulsation		[6]	R134a	POE	Grey cast iron/ grey cast iron Al390-T6/52100	0-1.72	from -10 to 130	88.9	2.4	600	Test performe d till scuffing	SEM AES Vickers' Rock-well's	PP SZO Micro – hardness Macro-hardness

to – and – fro		[7]	R134a R600a	POE MO	(100/102Cr6)/ LM13AE109	0.8-4	5-110	5 15 20	0.098- 0.13	7200	WT GZ	EDX SEM	SZO PP
rotation and pulsation		[8]	R134a Air	POE	PTFE/ grey cast iron Nylon 6,6/ grey cast iron Polyamide/ grey cast iron PEEK/ grey cast iron WP122 / grey cast iron WP191 / grey cast iron Vespel SP-21 / grey cast iron Vespel SP-211 – / grey cast iron HPV – PEEK/ grey cast iron PEEK, PEEK with carbon admixture/ grey cast iron PTFE/aluminium390-T6 PEEK/aluminium390-T6	0.172	60	45-225	2.4	600	WT GZ	EDX SEM	SZO PP
rotation and pulsation		[9]	CO_2 R410A	POE	Al390-T6/52100	0.34- -1.4	60	222- 3336	2.4	600 1200 1320 1500	Surface temperatu re WT ST Electric resistance of contact	SEM AES	PP SZO
rotation and pulsation		[10]	R410A	POE	Grey cast iron / tool steel Grey cast iron / tool steel + TNi	2		295 490 685	0.1425 0.725 1.425	till scuffin g	WT Time to scuffing	SEM EDX	PP SZO
rotation and pulsation		[11]	R134a	PAG	Al390-T6/52100	0.17	121	222.5 (co 15s +222.5N do zatarcia)	2.4	600	Test performe d. Till scuffing	SEM	PP

rotation and pulsation		[12]	R600a	MO	AlSiCuFe /100Cr6	277	75	350	0.95	12600	WT GZ	EDX Brinell's	SZO Hardness
rotation and pulsation		[13]	CO_2 Air O_2 N_2 R134a	–	Grey cast iron / grey cast iron	2.8 4.1	21-22	45.4	2.4	600	WT GZ	XPS SEM AES	SZO PP
rotation and pulsation		[14]	R407C	POE	Grey cast iron /SKH51+ TiNI Grey cast iron /SKH51+TiNII Grey cast iron /SKH51+TiAlN Grey cast iron / SKH51+WC/C Grey cast iron / SKH51+DLC Grey cast iron / SKH51 carburized Grey cast iron / SKH51 nitrided	0.9	20 70	176 440	0.182 0.91	3600 36000	GZ WT	SEM EDX	PP SZO
rotation and pulsation		[15]	CO_2 Air R600a	–	Steel 120+DLC/52100	0.1	20	445	0.21 0.33	1800	WT GZ	SEM EDS Raman's spectroscopy	PP SZO
rotation and pulsation		[16]	R12 R134a	MO AB PAG POE	Grey cast iron/ tool steel	1.6 0.17	81 118	45-4450	0.51	3600	WT GZ	XPS	PP SZO

The authors of many analysed works **[L. 6**, **8–9, 11, 13, 16]** used the same stand for their tests (**Tab. 1**). It made possible to apply power in the range from 45N to 4450 N. The disc could rotate with maximum speed 2000 rps and it could oscillate. There was the possibility to control the chamber temperature in the range from -20°C to 130°C with the use of liquid flowing through the upper rotating roller. The temperature was controlled by the outer thermostat. The chamber could work under pressure from 27 Pa to 1.72 MPa. The friction process was controlled with the computer. The friction element was the disc with the pin. The pin dimensions were: the diameter – 6.4 mm and the length – 8.8 mm. In order to locate a thermocouple in the pin, there was made a hole of 1 mm situated in the distance of 2 mm from the surface. The disc diameter was 75 mm, and its thickness was 6.4 mm.

The second stand (**Tab. 1**) enabled the authors of the works **[L. 5**, **10, 15]** to test the wear of materials applied in rotary (blade) compressors in the friction pair created by the compressor blades and body. The used friction machine had a pressure chamber designed for maximum pressure being 20 bar. For the wear tasks they applied samples made of materials used for the production of the real compressor blades and bodies which ensured the reflection of such properties like hardness and roughness.

The tests presented in the work **[L. 7]** were carried out on a modernised machine Phoenix TE77. This device is based on the longitudinal motion of the pin or ball on the plate in the oil bath. The used friction connection models the pair of the hermetic compressor.

The work **[L. 4]** presents tests of the materials of which crankshaft bearings in piston compressors are made. The test stand was a friction machine with a high-pressure chamber where samples being in the refrigerant polluted oil bath were static loaded. The loading value was chosen so that its dynamic character referred to real compressors.

The article **[L. 14]** presents the situation where for the wear test they used a modified machine Falex in which a linear contact is obtained in the friction pair. The samples covered with coatings applied in the rotary compressors were located in the high-pressure chamber.

The authors of the works **[L. 12]** presented tests of the friction pairs of the block-on-ring type; the tests aimed at determining the wear value in the pair: crankshaft neck – connecting rod big end in the piston compressors. Beside the chemical constitution of worn surfaces and wear products they also analysed the influence of wear on hardness of mating materials.

3. DESIRED PARAMETERS OF OWN STAND

The Institute of Machines and Motor Vehicles of Poznań University of Technology plans to create a universal test device for a quantitative evaluation of anti-wear and anti-friction properties of mixtures: oil – refrigerant. In order to reflect conditions being in real systems the desired parameters of the own stand have been determined (**Tab. 2**).

Table 2. Desired parameters of own stand
Tabela 2. Pożądane parametry własnego stanowiska

Parameter	Kind of motion (pair)	
	rotation and pulsation	reciprocating
Loading range [N]	from 45 to 4450	from 5 to 20
Zakres prędkości względnych [m/s]	from 0.1425 to 2.85	from 0.098 to 0.13
Temperatures of working refrigerant [°C]	from -10 to 130	from 5 to110
Pressures of working refrigerant [MPa]	0-10.8	from 0.8 to 4
Measured values describing the process	friction force wear electric resistance of contact	friction force wear

Parameters specified in **Table 2** are minimum values (ranges) for the desired parameters of built stand. An important aim is also to adapt this stand to size and shape of the samples which enables them to analyze the chemical composition of worn surfaces and wear products using the most popular spectrometers (SEM, AES, EDX). Currently completing loading component research device that meets the criteria on the research parameters set out in the paper.

CONCLUSION

At present, there is no universal oil for refrigeration compressors. Oil should be chosen for the suitable compressor and refrigerant. Due to more severe rules concerning the application of refrigerants the new refrigerant appear. The influence of the mixture of new refrigerant and oils on the wear of the compressor elements should be investigated. For this reason, the construction of the stand pin-on-disc type is foreseen. The stand will be equipped with the chamber for testing the wear of the moving pairs in the presence of oil and refrigerant. For modelling the compressor operation conditions the chamber will be able to control the refrigerant pressure and temperature in order to control the state of the refrigerant phase. Besides, the possibility to control pressure force and pin speed is planned. Also, detailed wear tests in the atmoshere of different refrigerants are intended to be performed.

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Streszczenie

Pożądaną cechą oleju smarującego sprężarki chłodnicze jest rozpuszczalność w czynniku chłodniczym w pełnym zakresie temperatur roboczych. Umożliwia to powrót większości oleju „wypompowanego" do obiegu chłodniczego do układu smarowania. Olej wydzielony z czynnika i wprowadzony do układu smarowania zawiera jednak pewną jego ilość, zatem można uznać, że elementy sprężarek smaruje mieszanina oleju i czynnika chłodniczego o własnościach z pewnością gorszych niż własności czystych olejów smarowych.

W dobie wymiany starych czynników chłodniczych na nowe, bardziej przyjazne środowisku, duże znaczenie ma ich kojarzenie z odpowiednimi olejami sprężarkowymi. Obok wspomnianego wymogu „rozpuszczalności" konieczne jest zapewnienie również odpowiednich własności przeciwtarciowych i przeciwzużyciowych (mieszanin „olej–czynnik chłodniczy"). Dlatego w referacie przeanalizowano informacje literaturowe o stanowiskach badawczych pozwalających ilościowo oceniać ten problem i sformułowano założenia do budowy własnego, uniwersalnego urządzenia badawczego.