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SPECIFICITY OF THE LUBRICATING OIL OPERATION IN THE REFRIGERATION COMPRESSORS

SPECYFIKA PRACY OLEJU SMAROWEGO W SPRĘŻARKACH CHŁODNICZYCH

Key words:

refrigerant & oil mixture, compressors elements damages, friction and wear

Słowa kluczowe:

mieszaniny olejów z czynnikiem chłodniczym, uszkodzenia elementów sprężarek chłodniczych, tarcie i zużywanie

Summary

Generally, in compressor refrigeration systems, compressor oil mixes with refrigerant. This deteriorates the thermodynamic properties of the refrigerant and protective (tribological) properties of lubricating oil.

This paper presents the oil-operating environment in refrigeration compressors as well as reasons for compressor element damages arising mostly in the effect of unfavourable properties of oil contaminated with refrigerant.

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INTRODUCTION

The aim of refrigeration installations is to decrease the temperature of a cooled space. A lower temperature is obtained through the warm reception, made by the refrigerant circulating in the system, from the cooler area and the heat transfer to the warm area. In order to perform this task, energy from outside should be delivered. Most often, the compressor is used as a driving element for the circuit functioning.

Apart from the compressor, the refrigeration system contains a condenser, a control valve and an evaporator. The compressor is to compress refrigerant from the low pressure to the high pressure. In the effect of compression gas is heated up. The refrigerant from the compressor gets to the condenser where the ambient refrigerant (air, water) is cools hot gas causing refrigerant condensation. Next, the refrigerant being in the liquid phase gets, through the regulating element, to the evaporator where liquid gas evaporates absorbing ambient heat and thus cooling the space.

The compressor refrigeration system operates through sucking, by the compressor, refrigerant vapours leaving the evaporator. Vapours compression causes the increase of their pressure and temperature. Vapours are directed to the oil separator where oil is separated from refrigerant vapours and then vapours go to the condenser where in the effect of air or water cooling condensation takes place at constant pressure and temperature. The condensed refrigerant is flows to the throttle valve. The valve causes slackness of the refrigerant flowing to the evaporator. In the evaporator, in the effect of the warm reception from the cooled medium, evaporation takes place at the constant pressure and temperature.

In refrigeration systems, the hermetic compressors are generally used. Sucked gas gets to the compressor through the gland suction situated in the casing lower part. Flowing in the lower part of the electric motor it cools it additionally. Generally, oil drops are separated from the sucked gas and flow to the oil sump. After coming through the motor, the refrigerant meets mechanical elements causing its compression. The refrigerant compressed vapours are pressed through the discharge branch.

The refrigeration system operation is refrigerant circulation among the circuit elements. In the effect of different pressures and temperatures the refrigerant in the system is in a different phase. In real refrigeration systems, oil is caught by the refrigerant and circulates in the circuit. In order to obtain the proper operation of the compressor, proper lubrication of moving joints is necessary. When the compressor is not lubricated it isn't obvious that there is no oil. Because of defective installation oil can be in wrong places, for example, in incorrectly mounted suction pipes.

REASONS OF COMPRESSORS DAMAGES

Reasons and frequency of compressors failures are connected with different and specific operation conditions of individual parts and units. Long-term statistics made all over the world allowed to determine the percentage of damages of individual parts and units of piston compressors which are presented in the **Figure 1 [L. 1]**. The literature analysis (**Fig. 1**) showed that over 70% of damaged compressor parts could be exposed to the action of the mixture oil – refrigerant.

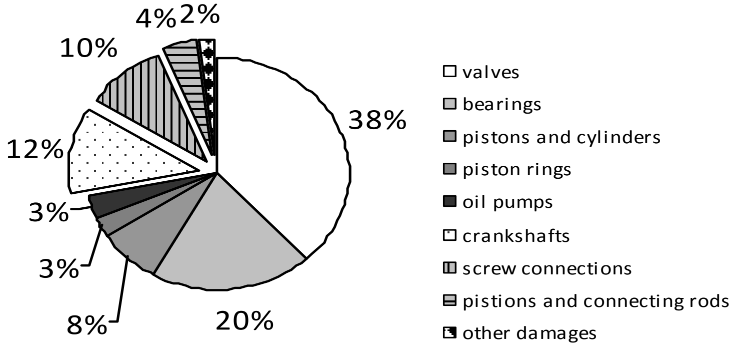

Fig. 1. Share of damages of individual parts and units of piston compressors [L. 1]
Rys. 1. Udział uszkodzeń poszczególnych części i zespołów sprężarek tłokowych **[L. 1]**

Mechanical reasons of compressors failures are: the lack of oil, improper lubrication (improper oil, creation of mixture of liquid agent with oil, improper oil properties) and liquid impact.

The lack of oil leads to early compressor scuffing. The compressor oil loss can be connected with no oil return from the installation or with its insufficient return. So, oil should return from the installation quickly and in sufficiency. The refrigerant is an oil carrier in the installation, so the refrigerant lack can be also connected with no oil return to the compressor. The refrigerant insufficiency or its lack causes the decreased flow speed being unsatisfactory for liberation. In theory, the application of the low pressure sensor cannot make the compressor to start during the stand by or to stop during the operation. However, there are such situations that the amount of refrigerant is insufficient for the right oil circulation though the the oil pressure is above the critical value set on the low pressure sensor. The refrigerant excess can also lead to the compressor failure because of increased pressure.

One of the main reasons of the compressor damage is flooding with liquid refrigerant during the stand by. Besides, during the stand by, the refrigerant migrates to oil as a result of oil and refrigerant vapours pressure difference. During the stand by oil in the casing is diluted with a big amount of the liquid refrigerant. Oil with the refrigerant is heavier than pure oil and that is why it is on the casing bottom. The refrigerant migrates to pure oil situated at the casing top.

The wrong operation of the refrigeration installation causes the compressor suction of liquid refrigerant together with vapours. It can happen when refrigerant vapours in the evaporator are not sufficiently heated. A small amount of liquid refrigerant due to decreased flow speed can be separated in the suction tube and flow down to the compressor bottom causing oil dilution. The oil pump pumps oil with the refrigerant to the bearings where in the effect of friction the temperature increases leading to the refrigerant evaporation and resulting in oil insufficiency.

At the moment when the compressor is switched off, there can occur a sudden pressure drop causing rapid evaporation of the refrigerant emanating from oil and creating a mixture in the foam form. In case the foam gets to the operating elements, oil washing away takes place.

Big amounts of liquid refrigerant cannot evaporate causing the liquid impact to the compressor elements. The situation is similar in case of a big amount of foam which in the effect of being sucked, e.g. to cylinders, can cause the liquid impact.

WORKING ENVIRONMENT OF REFRIGERATION COMPRESSORS

Refrigerants

The refrigerant is a substance taking part in the heat exchange in the refrigeration mechanisms; it takes heat in the evaporation process in the evaporator at low temperature and transfers it back during condensation at higher temperature and pressure **[L. 2]**.

For many years, different kinds of compounds were used as refrigerants. The industry development caused the use of refrigerant of better and better thermodynamic and service parameters; however, they did not pay attention to the environment protection. The **Figure 2** presents classification of natural and synthetic refrigerants **[L. 3]**.

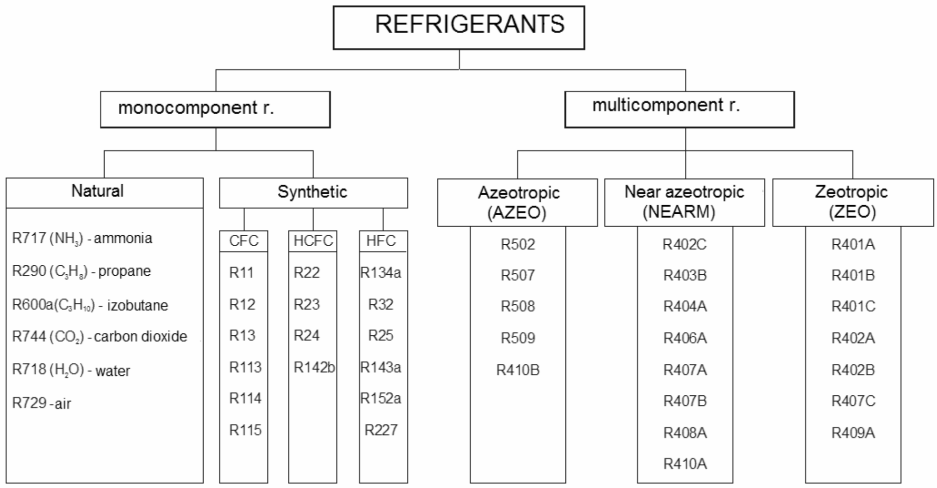

Fig. 2. Scheme of classification and terminology concerning natural and synthetic refrigerants [L. 3]
Rys. 2. Schemat klasyfikacyjny i terminologia naturalnych i syntetycznych czynników chłodniczych **[L. 3]**

The Montreal Protocol signed in 1987 and implemented in 1989 prescribed to eliminate, according to the determined schedule, agents of the CFC group and later also HCFC agents for the protection of the ozone layer. In 2000, the European Union, with the Board Disposition No. 2037/2000, introduced rules concerning dealing with substances reducing the ozone layer **[L. 4]**. In Poland, the above disposition is realised by the act concerning substances reducing the ozone layer **[L. 5]**. This act, apart from many duties laid on subjects making use of substances reducing the ozone layer, also determines the date to which certain determined agents are allowed to be used. The agents of the group HCFC (e.g. R22) can be applied only to the end of 2009, whereas the recovered and regenerated agents of this group can be applied till the end of 2014 unless the European Committee shortens this term **[L. 4]**.

At present, they look for agents being safe for the environment which can substitute the ones withdrawn from the market. The **Table 1** presents a list of withdrawn and alternative agents for different groups of refrigeration mechanisms (for serviced and new built mechanisms) **[L. 6]**.

Table 1. Refrigerants in different fields [L. 6]
Tab. 1. Czynniki chłodnicze w różnych działach **[L. 6]**

Kind of device	Withdrawn agent	Alternative agent	
		Serviced mechanisms	New mechanisms
Home refrigeration mechanisms	R12	R409A	R134a R600a (isobutane)
Commercial refrigeration mechanisms	R12 R22 R502	R409A, B R22 R408A R22	R134a R404A, R407C R404A R507
Refrigeration transport	R12/R500 R502	R409A, B R22 R408A	R134a R404A R507
Big mechanisms in food processing	R22 R502	R408A R22	NH_3, CO_2 R134a, R290 R404A, R507 R407C
Car air conditioning	R12		R134a, CO_2
Stationary air-conditioning (central systems) Individual mechanisms	R11 R114 R12, R22 R22		R123 R124 R134a, NH_3 R407C
Heat pumps	R22		R134A, NH_3 CO_2, R290
Low temperature mechanisms	R13	R23	R23

Properties of oil applied for refrigeration systems

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. So, it should be made sure that oil and refrigerant cannot create a chemical reaction, e.g. creating aggressive compounds causing corrosion.

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. So, the elimination of oil solidification in low temperatures is important. Oil should also have small hygroscopicity due to the possibility of water appearance in the system **[L. 6]**.

According to the standard DIN 51503-1 compressor oil are assigned to definite groups of refrigerants. It specifies oil quality classes **[L. 6]**: KAA (ammonia insoluble) , KAB (ammonia soluble), KC (for refrigerant of groups CFC and HCFC), KD (for refrigerant of groups FC and HFC), KE (for refrigerant of the hydrocarbons group HC).

In the refrigeration installation the system oil – refrigerant characterizes with the complex dependence. In case of exceeding the mutual miscibility, a part of the refrigerant is absorbed by oil (**Fig. 3**).

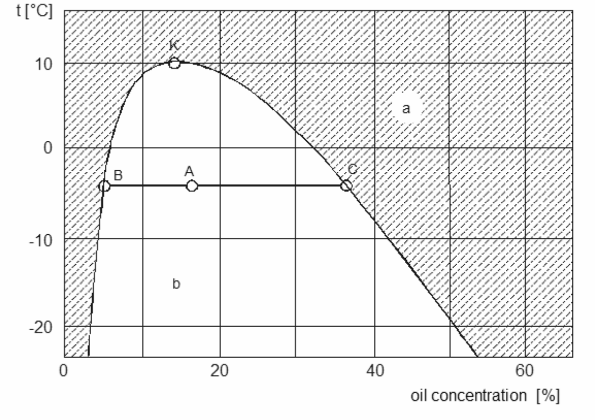

Fig. 3. Non-miscibility zone of refrigerant R22 with mineral oil: a – homogenous solution area, b – stratification area [L. 6]

Rys. 3. Strefa niemieszalności czynnika R22 z olejem mineralnym: a – obszar roztworu jednorodnego, b – obszar rozwarstwienia **[L. 6]**

The refrigerant solubility in oil is relative, among others, to the oil base. Depending on the mixture ratio and temperature, the mixture of oil and refrigerant can be of one- or two-phase character (**Fig. 4**).

The compound of oil and refrigerant should be matched so that there is no stratification, causing oil washing away from friction pairs, could not occur. Solubility of oil in the refrigerant depends on the oil base and the refrigerant.

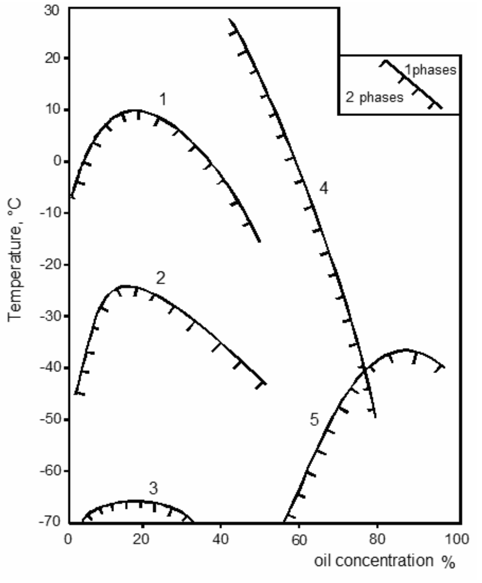

Fig. 4. Areas of existence of one oil phase or two phases in the compound with the refrigerant R22, depending on the temperature for different kinds of oils: 1 – oils of naphthenic type, 2 – oils being mixtures of naphthenes and alkylbenzenes, 3 – alkylbenzenes, 4 – polyalfaolefins (PAO), 5 – polyglycols [L. 6]

Rys. 4. Obszary istnienia jednej lub dwóch faz oleju w mieszaninie z czynnikiem chłodniczym R22, w zależności od temperatury dla różnych rodzajów olejów: 1 – oleje typu naftenowego, 2 – oleje stanowiące mieszaninę naftenów i alkilobenzenów, 3 – alkilobenzeny, 4 – polialfaolefiny (PAO), 5 – poliglikole **[L. 6]**

Complex relations in case of the mixture oil – refrigerant make the lubrication and anti-wear properties much worse than for pure oil. In order to recompense the improper properties, one introduces to oils anti-wear and anti-scuffing additives and uses oils of higher viscosity due to oil dilution with the refrigerant.

As the problems are complex, at present, there are no established international standards on requirements concerning oils applied in refrigeration compressors. The complex dependences are influenced by a variety of refrigerants, oils compositions and refrigeration installations construction.

MODEL TESTS OF FRICTION PAIR IN OIL – REFRIGERANT ENVIRONMENT

After the literature review, one can state that the refrigeration compressors moving elements are subjected to various kinds of wear depending on oil mixtures and refrigerants with which the compressors work.

In Poland no one up to now made a research work on the influence of the compressor elements wear in the presence of various mixtures of oil and refrigerant. The hitherto tests were executed on model stands, most often of pin-on-disc type in the presence of different oils and refrigerants **[L. 7–14]**. The tests were performed in special chambers ensuring the right pressure and temperature of the refrigerant. The obtained results confirm irrefutable the influence of the mixture of various oils and refrigerant on the different wear of friction elements.

CONCLUSIONS

Currently there is a need to test all kind of oil mixture with new refrigerants. The problem are existing refrigeration installations in which, in accordance with a law, the refrigerant should be exchanged soon. Nowadays, there is no universal oil for refrigeration compressors.

In order to investigate the influence of the mixture of new refrigerants and oils on the compressor elements wear, the construction of the stand type pin-on-disc is planned. The stand will be equipped with a chamber for testing the moving pairs wear in the presence of oil and refrigerant. For modelling the compressor operation conditions the chamber will have the possibility to control the pressure and temperature of the refrigerant in order to control the refrigerant phase state.

The Institute of Machines and Motor Vehicles of Poznań University of Technology already possesses a device for refrigerant emptying and filling the refrigeration installation. The device is necessary as the majority of refrigerants, in the light of valid rules, are gases being the control subject in accordance with the act concerning substances reducing the ozone layer **[L. 5]**. The detailed wear tests in the atmosphere of different refrigerants are planned to be performed.

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Streszczenie

W sprężarkowych układach chłodniczych najczęściej dochodzi do mieszania oleju sprężarkowego z czynnikiem chłodniczym. Pogarsza to własności termodynamiczne czynnika chłodniczego i oczywiście własności ochronne (tribologiczne) oleju smarowego.

W referacie przedstawiono środowisko pracy oleju w sprężarkach chłodniczych oraz przyczyny uszkodzeń elementów tych sprężarek, w większości wynikających z niekorzystnych własności oleju zanieczyszczonego czynnikiem chłodniczym.