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A new structure and theoretical analysis on leakage and performance of an oil-free R290 rolling piston compressor

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ABSTRACT

Lubricating oil improves the reliability of compressors and systems, whereas increases the system complexity. Compared with other types of compressors that have oil-free models, a rolling piston compressor has more leakage paths and bigger leakage loss. Therefore, the leakage is an important problem to be solved in order to develop an oil-free rolling piston compressor. The paper put forward a new structure of rotary compressor adopting a low pressure shell, connecting the cavities within piston and behind vane to the cavity at suction pressure and using radial compliance mechanisms. Then the leakage models were developed to calculate the mass flow rates within both the present rolling piston compressor without any oil as sealant and the new structure of oil free compressor. Results showed that by the new structure, the influences of leakage on the performance of a R290 oil free rolling piston compressor can be largely decreased.

Nouvelle structure et analyse théorique des fuites et de la performance d'un compresseur sans huile à piston roulant au R290

Mots clés : R290 ; Compresseur à piston roulant ; Sans huile ; Fuites ; Performances

1. Introduction

The production and consumption of R22 currently used in room air conditioners in China have been frozen since 2013 and will be phased out by 2015 due to its impacts on the ozone layer. The alternative refrigerant R410A was developed twenty years ago and known as the transitional refrigerants because of its higher GWP. Despite that, it has been still widely used in many countries. At present, some companies promote several other synthetic alternatives, for example, Daikin promotes R32, and Honeywell promotes L41. Their GWPs are lower than that of R410A. The natural working substance propane has

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Nomenclature

e	eccentricity of crankshaft (m)
L	length of leakage path (m)
L_f	equivalent channel length (m)
M	Mach numbers at inlet of leakage flow
P	pressure (Pa)
R_c	radius of cylinder (m)
Re	Reynolds number
V	flow velocity($m \cdot s^{-1}$)
W	width of leakage path (m)

Greek symbols

δ	gap value (m)
k	the adiabatic exponent of refrigerant
μ	dynamic viscosity (Pa·s)
υ	specific volume of refrigerant vapor ($m^3 \cdot kg^{-1}$)
ρ	density ($kg \cdot m^{-3}$)
φ	discharge angle (rad)

Subscripts

1	inlet of leakage flow
2	outlet of leakage flow
c	compression chamber
s	suction chamber

been chosen as the main alternative for R22 in Chinese room air conditioner industry because of its excellent environmental protection feature and thermal physical properties. The transformation for the production line of R290 room air conditioners and compressors has been aided by Multilateral Funds financially which is dedicated to reversing the deterioration of the earth's ozone layer.

One of the important measures to improve the safety of R290 room air conditioners is to limit the R290 mass within system. The main way to reduce R290 charge in an air conditioner is to reduce the internal volume of heat exchangers and liquid line pipes, for example, by adopting the small diameter tube for condenser. As a result, the R290 content in the compressor of system becomes relatively larger. Therefore, it is necessary to reduce the R290 charge in the compressor (Wu et al., 2012).

The compressor used in a room air conditioner now, as shown in Fig. 1, is mainly the rolling piston type rotary compressor with high pressure shell, whose oil sump is exposed to the discharge pressure, therefore a great amount of R290 is dissolved in oil. Two basic approaches to reduce the R290 mass in the compressor are to lower oil charge in the compressor (Gao et al., 2012) and to use oil with low R290 solubility. On the other hand, oil in system can decrease the heat transfer effect of exchangers, increase the flow resistance and thus degrade the system performance (Youbi-Idrissi and Bonjour, 2008). Additionally, to deal with oil return, the system may be more complex. The decomposition of oil, the flow block of micro channel and other issues related to oil will affect the system's reliability. Therefore, it is of great significance to research and develop the oil free compressor R290 room air conditioning system.

In some ways, R290 is favorable for a compressor with an oil-free model. Compared with R22 and R410A, the difference

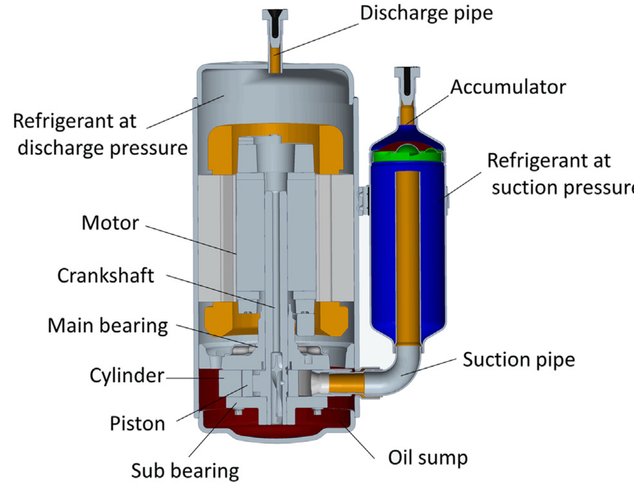

Fig. 1 – R290 rolling piston compressor with high pressure shell.

between discharge pressure and suction pressure of R290 compressor is smaller and, as a result, the loads on some friction pairs are smaller, too. The lower discharge temperature of R290 compressor reduces the working temperature of its friction pair. And the large specific heat of R290 is beneficial for us to cool the bearings with gas refrigerant. Admittedly, the viscosity of R290 vapor is lower and it would increase the leakage loss of oil-free rolling piston compressor. This is also investigated in this paper.

At present, reciprocating, scroll and linear type compressors all have their oil-free or semi-oil-free models (Bradshaw et al., 2011). But the rolling piston compressors have no oil-free version yet. For certain displacement, the integrated performances of rolling piston compressors are very excellent, such as: high COP, good reliability, low vibration and noise, and low cost. So they are widely used for room air conditioners now. Nevertheless, there is no paper has discussed technical issues about oil-free rolling piston compressor.

Besides lubricating friction pairs, the oil within compressor also plays a pivotal role in sealing leakage clearances, enhancing heat diffusion and thus ensuring the high reliability and performance of a compressor. The main technical problem of oil free compressors is undoubtedly the friction and wear. Compared with reciprocating or linear compressor, the rolling piston compressor has more leakage path and bigger leakage loss. So once the rolling piston compressor adopts the oil-free model, it is necessary to figure out how much the leakage loss is and how to limit the leakage loss and its effect on the compressor performance.

There were many studies on the leakage of rolling piston compressor in the past. Earlier at the beginning of developing rolling piston compressor, Paudeya and Soedel (1978) calculated and analyzed the effect of leakage on the performance of the compressor. Leakages through the clearance between cylinder and piston and the clearance between vane ends and cylinder heads were considered as a gas flow and the mass flows were calculated by nozzle model. A leakage loss of approximately 12% of the ideal mass flow was obtained. The reason for why the value was larger was that the effects of oil