available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/ijrefrig

Study on leakage via the radial clearance in a novel synchronal rotary refrigeration compressor

*Hua Yang**, *Zongchang Qu*, *Hui Zhou*, *Bingfeng Yu*

School of Energy and Power Engineering, Xi'an Jiaotong University, 28 Xianning West Road, Xi'an, Shaanxi 710049, China

ARTICLE INFO

Article history:
Received 11 January 2010
Received in revised form
3 May 2010
Accepted 11 August 2010
Available online 18 August 2010

Keywords:
Leakage
Rotary compressor
Loss
Refrigeration system
Compressor
Rolling piston

ABSTRACT

The leakage flow characteristics at the radial clearance between the rotor and the cylinder in a novel synchronal rotary (SR) refrigeration compressor were analyzed, and the oil–refrigerant two-phase leakage flow model was established. The leakage at different temperatures caused by wall velocity and pressure difference was calculated, and their influences on the total leakage were analyzed, respectively. The calculation results indicate that the leakage of the oil–refrigerant mixture decreases firstly and then increases with the increase in the temperature. However, the refrigerant leakage always decreases when the temperature increases. Moreover, the leakage caused by wall velocity has great influence on the total leakage, especially when the radial clearance is small.

Etude sur les fuites à travers l'espace mort dans un nouveau compresseur frigorifique rotatif synchrone

Mots clés : Fuite ; Compresseur rotatif ; Perte ; Système frigorifique ; Compresseur ; Piston roulant

1. Introduction

Rotary type compressors represented by the rolling piston compressor and the vane compressor are used more widely than reciprocating compressors in refrigeration and air-conditioning systems because they have advantages such as less components, simpler and more compact in construction, better dynamic equilibrium characteristics, quieter and smoother operation, and higher reliability. However, owing to the high relative velocity between the rotor and the cylinder, the cylinder and the sliding vane of the conventional rotary compressors, the frictional loss is high and then limits their performances and reliability. In order to overcome these disadvantages, a novel SR compressor has been developed in recent years, in which the high friction and severe wear caused by high relative velocity in the conventional rotary

* *Corresponding author*. Tel.: +86 29 82675258; fax: +86 29 82668691.
E-mail address: cherubxjtu@gmail.com (H. Yang).
0140-7007/$ – see front matter
doi:10.1016/j.ijrefrig.2010.08.007

Nomenclature

e	distance between cylinder center and rotor center [m]
H	rotor axial length [m]
L_{rc}	length from rotor center to cylinder inner wall [m]
P	pressure [Pa]
Q	leakage mass flow rate [kg s^{-1}]
R	radius [m]
S	solubility
T	temperature [K]
V	velocity [m s^{-1}]
x	quality of refrigerant
α	void fraction
θ	rotation angle [rad]
μ	dynamic viscosity [Pa s]
ρ	density [kg m^{-3}]
φ	discharge angle [rad]
ω	angular velocity [rad s^{-1}]
η_l	leakage loss (decrease in volume efficiency) = Q/ideal suction mass flow rate × 100 [%]

Subscripts

c	compression
cy	cylinder
d	discharge
g	gas
l	liquid
p	pressure difference
r	radial direction
ro	rotor
s	suction
v	wall velocity
z	axial direction
θ	circumferential direction

compressors are effectively reduced by the method of the cylinder and the rotor rotating around their own axis synchronously. Zongchang (2003) brought forward the SR compressor for the first time and described the operating principle and structural characteristics. Hui et al. (2005, 2009) established the kinematic and force models for the key components—cylinder, sliding vane, and rotor of the SR compressor. Hui et al. (2007) established the leakage model of the air SR compressor, and the leakage through the radial clearance is considered isentropic flow through the convergent nozzle and adiabatic frictional (Fanno) flow through the straight channel. Hua et al. (2008) calculated the friction forces and the friction power loss of the sliding vane for a SR compressor prototype with 96 cm^3/rev capacity, and the calculation results were compared with a rotary vane compressor with the same capacity. The results show that the total friction power loss of the SR compressor prototype is decreased by about 53.8%. In addition, Teh and Ooi (2009a,b), Teh et al. (2009) investigated the frictional losses, the performance of a rotating valve and the leakage loss for a revolving vane compressor which is similar to the SR compressor.

The radial clearance leakage is the key factor affecting the performance of the rotary type refrigeration compressors, which will influence the performance of the refrigeration and air-conditioning systems directly. Therefore, much research on the radial clearance leakage in rotary compressors has been carried out. Pandeya and Soedel (1978), Gybery and Nissen (1984) assumed that the leakage through the radial clearance was the leakage of pure refrigerant gas. They used the model of the one-dimensional isentropic flow through the ideal nozzle to calculate the leakage, which ignored the influence of the lubricating oil and the friction of the wall, and will lead to greater calculation error. Yanagisawa and Shimisu (1985a,b) analyzed the leakage on a rolling piston compressor in detail, and took the influence of wall frictional resistance into account. They established the leakage model based on the Fanno flow instead of the ideal nozzle model, but the leakage through the radial clearance was still assumed as the pure refrigerant gas leakage and the influence of the lubricating oil was ignored. Xiuling et al. (1992), Zhen and Zhiming (1994), Huang (1994) and Teh and Ooi (2009c) also ignored the influence of the lubricating oil. Leyderman and Lisle (1995) considered the influence of the oil on the leakage, but did not take the influence of the refrigerant dissolved in the oil into account.

In order to further study the leakage flow characteristic through the radial clearance in rotary compressor, Costa et al. (1990) carried out a visualization experiment on the leakage through the radial clearance in rotary compressor. They observed that the oil film adhered to the cylinder and the rotor walls stick together at the vicinity of the minimal

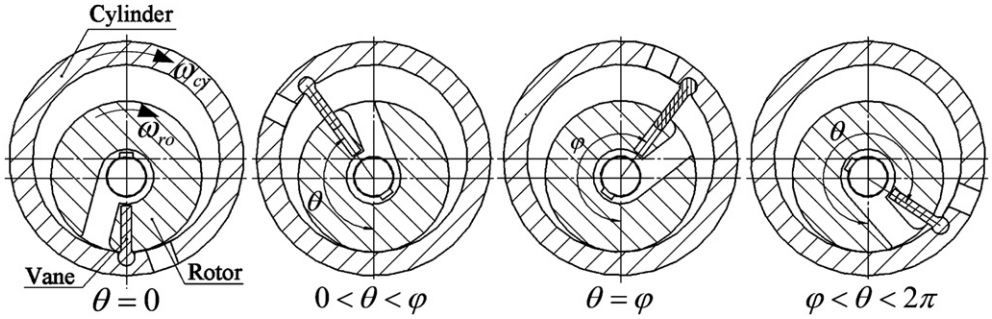

Fig. 1 – Cross-section diagram of a synchronal rotary compressor.