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Research of leakage characteristics of single screw refrigeration compressors with the Multicolumn Envelope Meshing Pair

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ABSTRACT

The Multicolumn Envelope Meshing Pair (MEMP) was proposed and has been applied for the single screw refrigeration compressor (SSRC) to reduce the wear of the meshing pair. However, the geometric model shows its changed shape of the leakage paths compared with the existing straight line envelope meshing pair (LEMP). It is necessary to research the leakage characteristics of the SSRC with MEMP and LEMP, to evaluate the value of the proposed MEMP. In this paper, the geometric model of the leakage paths between star-wheel and screw rotor is established. A two-phase leakage mathematical model for gas-oil flow is presented to predict the gas leakage rate of the SSRC with MEMP. The experiments of the performance of a SSRC with MEMP were conducted to verify the leakage mathematical model. Obtained results show the leakage of the SSRC with MEMP is a little bit smaller than that of the SSRC with LEMP.

Recherche des caractéristiques de fuite de compresseurs frigorifiques à monovis avec couple satellite-rotor d'enveloppe à colonne multiple

Mots-clés : Caractéristiques de fuite ; Compresseur frigorifique à monovis ; Couple satellite-rotor d'enveloppe de colonne multiple ; Modèle géométrique

1. Introduction

Single screw refrigeration compressors (SSRC) developed by Zimmern in the 1960s (Zimmern and Patel, 1972) are widely used in air compression systems and refrigeration systems (Wang, 1978). The performance of a newly produced SSRC is superior to that of the single piston compressor and the screw compressor (Bein, 1991; Zhang, 2007), but the discharge capacity decreases sharply several hundred hours after initial operation (Zimmern, 1990). This is because that the star-wheel tooth flank of the SSRC wears rapidly and the

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Nomenclature

u	Height of the envelope column (m)
P	Teeth number ratio between the star-wheel and the screw
A	Central distance between the star-wheel and the screw rotor (m)
d	Diameter of the envelope column (m)
b	Width of the leakage path (m)
l	Length of the star-wheel tooth meshing into the screw groove (m)
Δp	Pressure difference (Pa)
U	Wall velocity (m s^{-1})
$\dot{m}$	Leakage flow rate of the mixture (kg s^{-1})
x	Dryness of the mixture
S	Area of the leakage path (m^2)
d/D	Diameter ratio of the orifice to pipe
h	Axial leakage clearance (m)

Subscripts

g	Gas
l	Lubricating oil
m	Mixture
i	Number of the envelope column

Greeks

θ	Envelope angle (rad)
α	Star-wheel rotation angle (rad)
β	Inclination angle of the column, (rad)
ξ	Circumferential Angle of the boundary point. (rad)
μ	Viscosity of the fluid (Pa.s)
ε	Expansion coefficient
κ	Flow coefficient
λ	Correction coefficient
ρ	Density of the flow (kg m^{-3})

clearance between the star-wheel and the screw increases. In the existing design of the SSRC, the tooth flank contacts with the groove flank at its sharp straight edge and wore at this sharp straight at first. Structure of the tooth and the groove meshing pair of existing SSRC is called as with straight line envelope meshing pair (LEMP). In order to enhance the wear-resistance of the meshing pair, its profile must be improved. On the basis of column envelope profile proposed by Zimmern and multi-straight line envelope profile proposed by Feng (Feng et al., 2005), a new Multicolumn Envelope Meshing Pair MEMP was deduced by our group in 2009 (Wu and Feng, 2009).

This MEMP could significantly improve the wear resistance of the compressor (Li et al., 2013). However, leakage path shapes of the LEMP and the MEMP compared by Wu show that the leakage paths are changed (Wu, 2010). Through the qualitative analysis, the leakage characteristics of the leakage paths between the star-wheel and the screw are very different for the SSRC with LEMP and MEMP. Further more, the leakage characteristics are a very important features in the process of performance evaluation of the SSRC. Thus, it is necessary to investigate the leakage characteristic of the compressor with the MEMP. Several scholars had investigated the leakage characteristics of the SSRC with the LEMP (Jin and Lin, 1986; Li, 1994; Wu, 1996; Zhou, 1999). In there study, the parallel plate model and the wedge plate model were used to calculate the leakage rate. Because shapes of the leakage paths of the SSRC with MEMP are very different from the existing design meshing pair LEMP, the leakage characteristics of this new meshing pair MEMP must be investigated and to evaluate the performance of the compressor with the MEMP is good or bad.

In this paper, the geometrical model of the leakage path in the SSRC with MEMP is established. A two-phase leakage mathematical model for gas-oil flow is presented to predict the gas leakage rate through the leakage paths of the SSRC. In order to verify the model, an oil-injection SSRC with MEMP has been developed and its performance has been tested by the experiment. Obtained results are compared with that of the SSRC with LEMP. It is found that the leakage rate of the SSRC with MEMP is smaller than that of a single screw refrigeration compressor with LEMP.

2. Leakage path geometrical model

2.1. *The feature of the leakage path with MEMP*

2.1.1. *Leakage path*

As show in Fig. 1, there are 9 leakage paths in the SSRC. Path 1 is the clearance between the star-wheel tooth top and the bottom of the screw groove. Path 2 and path 4 are the axial clearance between the star-wheel tooth flank and the screw groove, path 3 and path 5 are the radial clearance between the star-wheel tooth flank and the screw groove. Path 6 is the clearance between the upper surface of the star-wheel tooth and the casing. Path 7 and path 8 are the clearance between the outer surface of the screw and the inside surface of the casing. Path 9 is the clearance between the outer surface of the screw and the inside surface of the casing at the discharge end.

Leakage rate through the leakage path is affected by the area and the shape of the clearance. So the leakage path shape should be discussed before the leakage analysis. The

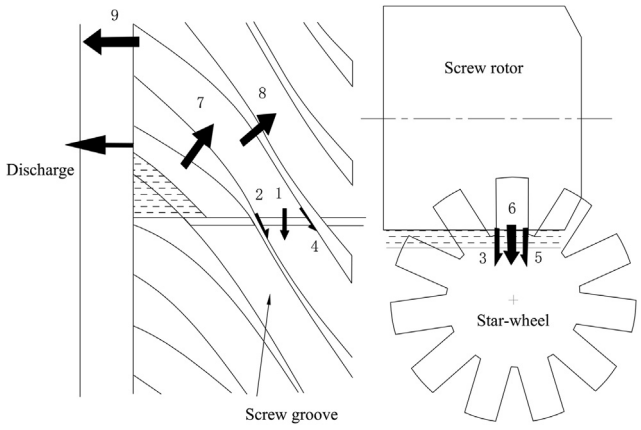

Fig. 1 – Leakage paths of the SSRC. This figure shows all of the leakage paths of the single screw refrigeration compressor.