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ABSTRACT

Straight line and column envelope type meshing pairs are two important meshing pairs in single screw compressors, while straight line envelope meshing pair is actualized but the other is still fail to meet industrial applications. The column envelope meshing pair of single screw compressors is proposed to improve the operating life of the compressor for poor wear resistance of existing straight line envelope meshing pair. To accelerate the industrial application of the new type compressor, leakage paths of two meshing pairs are analyzed and compared in this paper. Results shows that leakage paths of two type meshing pairs are rather different, this situation may one causation that column envelope meshing pair is remained in theory.

Keywords: single screw compressor; meshing pair; leakage path; envelope

1. INTRODUCTION

The single screw compressor (SSC) developed in 1960's (Zimmern, Ganshyam and Patel), is widely used in refrigeration and air/gas compression systems now. The structure of a typical SSC is shown in Fig. 1. It is mainly consisted of a screw rotor which cooperates with two star-wheels symmetrically located with respected to the screw to double the swept volume and balance the thrusts(Zimmern, Ganshyam and Patel, 1972). The operation of a single screw compressor can be divided into four phases: suction, sealing, compression and discharge. Star-wheels are driven by the screw rotor which is driven by the motor. In the compression phase, the flat up surface of star-wheel tooth, the root and the flanks of the flute cooperate with the tooth on screw rotor and the inner cylindrical surface of the housing case constitute a closed volume, which reduces gradually with the rotation of the screw rotor, and this leads up to a high pressure in the closed volume.

Volume Efficiency of a SSC is highly dependent on the clearances between screw rotor, star-wheel and house casing. Wear resistance of the meshing pair is the basic factor affecting the clearance, and then volume efficiency. Existing original meshing pair of SSCs is straight line envelope meshing pair (LEMP). Because its contact area on star-wheel tooth flank with the screw groove is a fixed straight line, its wearing resistance is poor. So a column (frustum) envelope meshing pair (CEMP) was proposed to enhance the wear resistance of the meshing pair, also the volume efficiency of the compressor (Zimmern, 1976). And a linear star-wheel tooth tip was proposed by Jensen (1998) to make the CEMP more fit for machining.

It is definitely that the column envelope profile will improve the wearing resistance of SSCs, but it is still fail to meet industrial applications. Reasons for this situation are various, besides it's machining, characteristics of the CEMP must be another important causation. So, this paper did a study on leakage paths of these two type meshing pairs, in order to find out that if leakage paths would decrease the practicability of CEMP. Leakage paths of two type meshing pairs are analyzed firstly, and then they are compared. Results show that these two meshing pairs have different type leakage paths, which means that optimization of CEMP is necessarily to minimize the leakage paths.

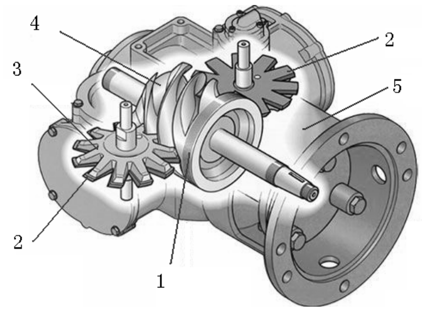

Fig. 1 Basic components of a typical single screw compressor
(1-screw rotor, 2- star-wheel, 3-support portion, 4-screw groove, 5-houseing case)

2. LEAKAGE PATHS OF LEMP

Leakage between the meshing pair will decrease volume efficiency of the compressor seriously. One phenomenon that a new SSC could operate with high efficiency but decrease sharply after hundreds of hours of working, means that leakage of a new SSC could be ignored and that of an operated SSC could not be ignored. Reason for this situation is that there is no leakage path exiting between the meshing pair or leakage paths could be ignored for a new SSC, and leakage paths could not ignored for an operated SSC for rapidly wear. So leakage paths can be divided into two types that initial leakage paths exists in new SSCs even though with a good manufacturing and wearing leakage paths would exist after hundreds of hours of working because of the attrition wear.

There are no initial leakage paths but the wearing leakage paths existing in LEMP in SSCs. So the compressor can operate with high efficiency at begin, however, the output decreases sharply after hundreds of hours of working.

2.1 Initial Leakage Paths

LEMP is proposed in accompany with the invention of SSCs. The screw groove flanks (SGF) is enveloped by straight lines on teeth flanks, so these straight lines are contact lines and are shown in Fig. 2.

It is clearly in Fig. 2 that a tooth divides a screw groove into high pressure chamber and low pressure chamber. And the contact lines of CEMP on the tooth are connected together from end to end, so no leakage paths from high pressure chamber to low pressure chamber exist in the screw groove.

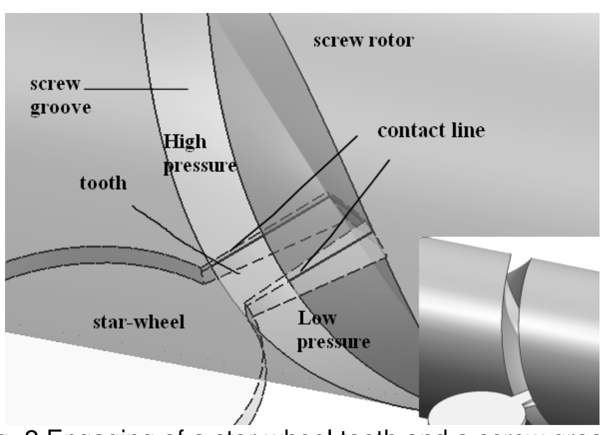

Fig. 2 Engaging of a star-wheel tooth and a screw groove

Another possible transverse leakage path, whose cross section is shown by dot matrix in Fig. 3, is from high pressure chamber in the screw groove to bear chamber under the star-wheel in the compressor. And the pressure in the bear chamber is low pressure too, so leakage can not be ignored. It is obviously that minimizing the distance from contact line from upper face of the tooth will reduce the size of transverse leakage paths. So in existing SSCs, this distance is restricted in very small size evenly smaller than 1mm. leakage could be ignored in this scale.

2.2 Wearing leakage paths

For the contact lines between fleetly moved tooth flank and SGF, abrasion is inevitable and quickly. It is shown in Fig. 4 that after hundreds hours of working, the edges (shown as broken lines) on the tooth flanks would be worn out because of vibrations and some minor geometrical errors. For this reason, leakage occurs through the gap between the tooth flank and the SGF, and this is wearing leakage paths.

Because of vibrations and minor geometrical errors, wearing happens definitely in operation, so wearing leakage paths is inevitable. For this reason, a CEMP was proposed to reduce the wearing. The tooth flank of CEMP is part of a cylindrical surface, and the contact line on the tooth flank with the rotor groove flank moves in one revolution and restricted in a contact area on the tooth flank.

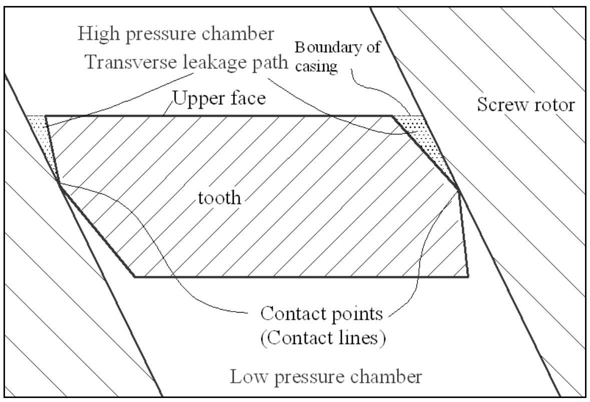

Fig. 3 Transverse leakage path of LEMP

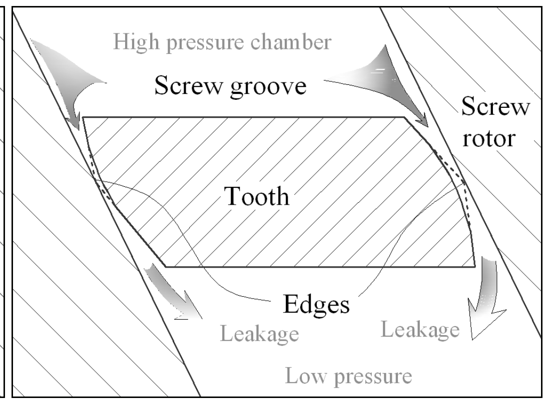

Fig. 4 Wearing leakage paths LEMP

3. LEAKAGE PATHS OF CEMP

The concept of CEMP was developed on the base of LEMP. The basic idea of this meshing pair is that replacing the straight line of the LEMP by the column, and the screw groove flanks (SGF) on screw rotor are changed in consequence. The contact area on star-wheel tooth flank with the SGF is changing with the rotation of the screw rotor. The meshing process of CEMP is shown in Fig. 5. Section lines of star-wheel teeth are hidden for the reason of clarity and the other white spaces in the figure stands for the screw groove. The circles in the figure stand for envelope columns, and it can be found that the contact position on the column between the column and the SGF is vary with the meshing position (Ⅰ, Ⅱ,Ⅲ) (Weifeng, Quanke and Jian, 2007).

So the contact area on the column between the CEMP is a wide cylindrical surface that the compressor will have better the wearing resistance and longer operating life.

To ascertain leakage path between the ECMP, it is necessary to confirm the contacting line between the CEMP firstly.

3.1 Contacting Area on Teeth Flanks

Contacting lines could be figured out according to column envelope principle exactly (Weifeng Wu, Quanke Feng and Jian Xu, 2007). It is a surface curve on the cylindrical tooth flank, and its position moves in a contact area with the rotation of the tooth and screw groove. The contact area at a section of the CEMP is shown in Fig. 5 by broken arc line with contact angle α. In most cases, value of contact angle α is limited in 0.524(30°), and the value of envelope column diameter d is close to the tooth width. This situation means that tooth thickness t must large enough to contain contact area in the tooth flank. For example, if diameter of the screw rotor is 150mm, the tooth width must bigger than 8mm to fit above conditions.

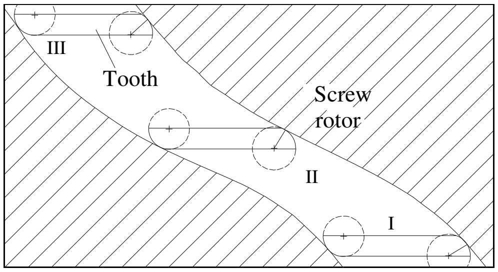

Fig. 5 The meshing process of CEMP

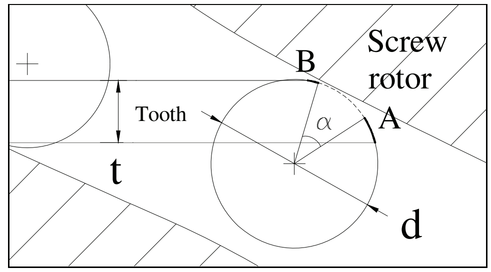

Fig. 6 The contact area on the tooth flank of CEMP

3.2 Initial Leakage Paths

Same with the LEMP, there is no initial leakage path existing from high pressure chamber to low pressure chamber in the screw groove, and transverse leakage paths exist. For the contact line moves when the tooth rotates, the transverse leakage path is varying too.

To minimize the transverse leakage path, upper face of the tooth can be set close enough to the upper border of the contact area, which is shown as upper end B of contact arc. When the contact line is through nether end A of contact arc, the size of transverse leakage path will be big enough that leakage can not be ignored.

3.3 Wearing leakage paths

For the better wear resistance of the CEMP, abrasion is slowly, the wearing leakage paths will be smaller than that of LEMP. On the other hand, for the abrasion of CEMP is separated in the contact area, the wearing leakage path will be narrow and long.

4. CONCLUSIONS

Above analysis shows that transverse leakage paths of LEMP can be ignored but that of CEMP can not be ignored, which will decrease practicability of CEMP. Wearing leakage paths of LEMP will grow quickly with the operation of the compressor, but that of CEMP will grow slowly, which will prolong the life time of the compressor. It results that initial performance of CEMP will worse than that of LEMP, but late performance of CEMP will better than LEMP. So checking the leakage of a new made CEMP that if leakage could be ignored and improvement of it are imperative under the situation.

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