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TIP SEAL BEHAVIOR IN SCROLL COMPRESSORS

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ABSTRACT

To achieve the performance of scroll compressors, both radial and axial sealing must be secured to avoid interscroll refrigerant leakages. The axial sealing may be obtained by using floating seals located in a groove found at the top of the involutes. The tip seal is pressed against the opposite scroll baseplate by the gas pressure maintained in the groove channel under the seal. The objective of this study was to investigate the dynamic behavior of floating seals in scroll compressors. Two different tip seals were investigated: a multi-blade tip seal and a monobloc tip seal. Several experiments were carried out in order to measure the pressure under the tip seal versus the crankshaft angle. Quick response pressure probes were used, as well as an instantaneous crankshaft angle indexer. The behavior of the tip seal was characterized by the type of leak path, which was determined with the pressure records.

INTRODUCTION

This study covers two types of tip seals: a multi-blade tip seal (Figure 1) and a monobloc tip seal (Figure 2). Both types have the same dimensions, provided that the blades of the tip seal are dry and pressed together and that the groove has the same dimensions.

Recall: Tip Seal Main Features

The tip seal is a very simple means of securing the axial tightness between scrolls with a limited contact force.

The tip seal takes up the axial clearance due to the difference in heights of the machined involutes, between the fixed scroll and the orbiting scroll, which suppresses the leak path. In the same way, small deformations of the scroll
baseplates can be taken up by the seals. Furthermore, the contact surface is minimized, so the friction energy losses are reduced. With tip seals, the performance is achieved without wear-in period and the efficiency remains the same in the long run, without any noise change or wear.

EXPERIMENTS

It was important to know how the tip seal behaves in order to optimize the design. In reference [1] indications are given about a monobloc tip seal in terms of leaks related to the clearance between the seal and the groove width. In this reference [1], experiments show that a minimum width clearance is the best solution for a monobloc tip seal and the results are explained with leakage computations [1]. In the present study, both multi-blade and monobloc tip seals were investigated by experimental methods based on pressure measurements.

Types of Leaks

The typical types of leaks (Figure 3) were considered for the interpretation of results:

First case: a single longitudinal leak
Second case: an inter-pocket leak
Third case: side pressures are equal

Experimental Apparatus

A scroll compressor inside a flanged shell was equipped with probes to measure the pressure under the tip seal in relation to the crankshaft angle. The pressure was measured at locations A, B, C on the fixed scroll (see Figure 4). The pressure probes were connected to vertical holes drilled as shown in Figure 5. A proximity probe was fitted to the lower bearing in order to link the time pressure measurement to the crankshaft position.

RESULTS

Static Pressure Measurement under the Tip Seal (Figure 6)

In this experiment, the leak pattern was characterized and the two types of tip seals were compared.
For the multi-blade tip seal, the pressure curve decreases steadily from point A to point C, for all operating conditions.
For the monobloc tip seal, the pressure drops rapidly from A to B. This proves that there are more leaks with the tested design of monobloc tip seal.
Pressure Measurement under the Tip Seal versus the Crankshaft Angle

In this experiment, the type of leak at A, B, C was determined by the pressure curve versus the time. The type of leak explains the tip seal behavior. B is the most interesting point, because it reveals the behavior of the tip seal with no side effects like A (discharge port pulsation influence) or like C (suction pressure influence). Note that for point B the dynamic pressure is drawn instead of the total pressure, which is nearly constant over one turn.

The dotted lines in Figure 9 represent the transducer signals for the passage of sealing point at B in relation to Figures 7 and 8. The dotted lines in Figures 11 and 14 are only for the situation in Figure 8 (inner sealing point).

The analysis depends on the probe location, as shown in table below:

<table>
<thead>
<tr>
<th>Point</th>
<th>A Probe location</th>
<th>B Pressure measurement</th>
<th>C Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probe location</td>
<td>Near discharge port (beginning of involute)</td>
<td>Intermediate pocket (middle of involute)</td>
<td>Involute suction (end of involute)</td>
</tr>
<tr>
<td>Pressure measurement</td>
<td>Total pressure (bar)</td>
<td>Dynamic pressure (mbar)</td>
<td>Total pressure (bar)</td>
</tr>
<tr>
<td>Analysis</td>
<td>Identify discharge port pulsation influence</td>
<td>Identify inter-pocket leak</td>
<td>Identify suction pressure influence</td>
</tr>
</tbody>
</table>

For the multi-blade tip seal the following behavior was reported:

The multi-blade tip seal behaves as if there was an isolated canal under it (Figure 3.1), in which the pressure is always higher than in the adjacent pockets. It has mostly a longitudinal leak.

At point A (Figure 10), the pressure varies significantly. The beginning of the tip seal appears to be completely under the influence of the pressure in the central zone of the scroll. The pressure curve seems to reflect the discharge pulsation, but modified with a slight delay and damping.

At point B (Figure 11), there is no synchronization between the maxima and the dotted lines, therefore the pressure value is independent from the theoretical pressure shift. The multi-blade tip seal behaves as if it was fed only by the longitudinal leak at point A with a gas outlet at point C. The oil fills the gap between the blades and allows the set of blades to expand; as a consequence, the multi-blade tip seal occupies the total groove width.

At point C (Figure 12), the pressure is constant and equal to the suction pressure.
For the monobloc tip seal the following behavior was reported:

The monobloc tip seal has both a longitudinal and a lateral leak (Figures 3.1 and 3.2).

At point A (Figure 13), there is again a dominant influence of the scroll central zone. At point B (Figure 14), there is a correspondence between the maxima and the dotted lines. The pressure varies at the same time and in the same way as the pressure on the HP side of the wall. Moreover, the dynamic pressure varies over a wide range of 300 mbar (200 mbar for the multi-blade tip seal). This demonstrates that the monobloc tip seal is more subjected to inter-pocket leaks and follows the theoretical pressure shift as shown in Figures 8 and 9. At point C (Figure 15), the pressure is constant and equal to the suction pressure.

**CONCLUSION**

These investigations helped to better understand how a tip seal functions and highlighted the differences between a multi-blade and a monobloc tip seal. The understanding of leak path patterns led to valuable information that enables a mastery of both types of seals.

**REFERENCE**

Figures

1. Longitudinal leak

2. Inter-pocket leak

3. Case with $P_1 < P_2$

Fig 3. Assumed leak patterns
Fig 4. Position of points A, B, C

Fig 5. Hole through involute wall for pressure probe
Fig 6. Static pressure under tip seal.
ARI conditions.

Orbiting Scroll

Fixed Scroll (FS)

Sealing point on LP side (outer/FS)

Fig 7. Theoretical minimum of pressure in B

Sealing point on HP side (inner/FS)

Fig 8. Theoretical maximum of pressure in B

Fig 9. Transducer signal
Saturation temperatures are in °C
Evaporating / Condensing