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THRUST BEARING BEHAVIOR in SCROLL COMPRESSORS

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ABSTRACT

The development of scroll compressors requires a precise study of the thrust bearing. The prediction of the contact behavior between the orbiting scroll and the housing-thrust bearing is one of the most important problems. This thrust bearing contact behavior has an influence on the lubrication, the compressor reliability and the compressor efficiency. Thus the understanding of this phenomenon thanks to Finite Elements Analysis (FEA) and lab measurements gave us some information to explain how the orbiting scroll wobbling motion is generated. Another benefit of this study is the knowledge about the creation of the oil film between the two parts while the compressor is running. A direct consequence is the possibility of creating a design which avoids the wear and tear of the thrust bearing, while reducing the qualification time of the product.

1. INTRODUCTION

The prediction of the contact behavior between the orbiting scroll and the housing thrust bearing is one of the most important issues. Generally, the thrust bearing is designed by experience or by experiments. This publication presents an alternative approach to understand more precisely the physical behavior of the orbiting scroll thrust bearing in operation.

This thrust bearing contact behavior has an influence on the bearings lubrication, the compressor reliability, the compressor efficiency. Thus the understanding of this phenomenon thanks to finite element simulation (FEA) and lab measurements gave us some information:

- to explain how the orbiting scroll wobbling motion is generated,
- to explain how the oil film between the two parts is created while the compressor is running,
- to avoid the wear and tear of the thrust bearing,
- to reduce the qualification time.
2. THRUST BEARING LUBRICATION

2.1 Lubrication theory

Lubrication is the process, or the technique employed to reduce the wear of one or both surfaces in relative motion to one another by interposing a lubricant between the surfaces to carry or to help to carry the load (through pressure generation). The goal of the lubrication theory is to determine the pressure distribution in the fluid volume, and hence the forces on the bearing components.

2.2 Journal and thrust bearing lubrication

**Journal bearing** is a simple bearing in which a shaft, or "journal", or crankshaft rotates in the bearing with a layer of oil separating the two parts through fluid dynamic effects. Rather than the lubricant just 'reducing friction' between the surfaces, letting one sliding more easily against the other, the lubricant is thick enough so that, once rotating, the surfaces do not come in contact at all. If oil is used, it is generally supplied under pressure by a hole in the bearing.

**Thrust bearing** is a particular type of rotary bearing. Like other rotary bearings they allow rotation between parts, but they are designed to support a high axial load while doing this.

3. LABORATORY MEASUREMENTS ON A REAL COMPRESSOR

Figure 1 : scroll set assembly

The results obtained by simulation have been confirmed with lab measurements. Three sensors were inserted in the thrust bearing to measure the vertical displacement of the orbiting scroll in operation. The sensors recorded the distance between the thrust bearing surface and the orbiting scroll plate. According to these results the motion of the plane of the orbiting scroll was deduced. This plate really performs a wobbling motion. The calculations results were confirmed.

4. FEA SIMULATION MODEL

4.1 General points

These mechanical simulation calculations were carried out with the Ansys Software. We assumed that the thrust bearing surface is rigid and that the orbiting scroll is flexible i.e. the orbiting scroll can experience deformation under loading : this is a non linear static mechanical approach. Opposite to the reality, in the FEA model, the thrust bearing surface moves in relation to the orbiting scroll which is fixed. Thanks to the non linear calculation, the orbiting scroll is free to exert a contact pressure or to let occur a gap.
4.2 Boundaries conditions: pockets pressures

To simulate precisely a turn of the crankshaft, calculations every 3° of crankshaft angle were carried out. Our thermodynamic simulation software gave the pocket pressure position and pocket pressure for each crankshaft angle. An issue was to apply the boundaries conditions of the pocket pressure for each angle of crankshaft. In fact the meshing of the orbiting scroll remains the same for all calculations, whereas the pocket position and pocket pressure change during a turn of crankshaft. A computer program was written to apply automatically, and independently of the grid, the pressure inside the involutes. In this process, the elements boundaries did not correspond to the pocket pressures boundaries.

Note: for the following results, only 6 positions out of 120 were post-treated in this document.

Figure 2: mobile scroll loading
5. **FEA SIMULATION RESULTS**

5.1 **Orbiting scroll wobbling motion obtained by simulation**

The first result is the visualization of the vertical motion of the orbiting scroll on its thrust bearing. This motion corresponds actually to a wobbling motion in operation. In the following views, we can imagine the rotation motion uneven, rocking and unsteadily from side to side alternately.

![amplified vertical motion](image.png)

Figure 3: amplified vertical motion
5.2 Results focused on the thrust bearing contact

The more interesting results are precisely those concerning the thrust bearing contact behavior. Two types of results are extracted below:

5.2.1 Gaps: the grey area corresponds to the gap i.e. when the orbiting scroll takes off and when a separation occurs between the 2 parts.

Figure 4: gap zones for the thrust bearing
5.2.2 Contact pressures: the grey-black area corresponds to the contact pressure i.e. the area where the orbiting scroll exerts a vertical force or pressure to the thrust bearing.

![Contact pressures at various crankshaft angles](image)

Figure 5: contact pressures on the thrust bearing
5.3 Explanation of the thrust bearing lubrication

Knowing that the thrust bearing is supplied with oil in its center, it is important that the oil has a passage from the inner diameter of the thrust bearing to its outer diameter.

The wobbling motion can be seen as an instability harmful to the compressor, but in fact this motion creates between the parts a gap which rotates during a turn of the crankshaft.
Thus an annular oil circuit is created driving an oil wave around an axis with a flow between the parts. Only a little flow can escape at the periphery.

The above passage corresponds to a wave (grey area) which performs a turn on the thrust bearing during a turn of the crankshaft. This wave contributes to supply the thrust bearing with oil and to create the oil film.

Indeed, as the “wave” rotates, the oil is carried into the active part of the bearing (grey area), where it is compressed and the oil viscosity prevents the oil from escaping. As a result, the bearing glides on a layer of oil.

In the previous views (Fig.6), we can see the black dotted line where the oil is compressed, forming a lubricating wedge i.e. where the layer of oil is in a hydrodynamic state.

The black arrow indicates the direction of the motion.

![Figure 7: oil film pattern](image)

6. CONCLUSION

This FEA simulation gave us some very interesting information regarding the behavior of the orbiting scroll on the thrust bearing while the compressor is running. The distortion of parts leads to a hydrodynamic state for the oil flow. The oil flow is mainly tangential and not radial following a polar coordinate system.

It enabled us to highlight and to visualize the phenomenon for the first time and to confirm our point of view. It increased our competency.

It enabled us to modify the geometrical shapes and to optimize the thrust bearing behavior in order to have the best reliability and the best efficiency for all of our compressors.

To sum up, thanks to this FEA calculations, we acquired:

- A better comprehension how the thrust bearing is lubricated
- A better technique to design the thrust bearing in order to avoid wear and tear
- A better qualification time.