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Cross Sectional View of Scroll Compressor

It is significant to improve thrust slide-bearing for efficient scroll compressors
The theoretical study shows that friction power loss drastically decreases with an increasing outer-to-inner radius ratio.
The purpose of this study is to provide further experimental verification of the theoretical prediction for optimal design guidelines of the thrust slide-bearing in the scroll compressors.
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Contents

1. Outline of Thrust Slide Bearing Model

2. Theoretical Lubrication Analysis of Thrust Slide Bearing

3. Experimental Lubrication tests to Verify Theoretical Results

4. Conclusions
### Outline of Thrust Slide Bearing Model

<table>
<thead>
<tr>
<th>Actual Friction Area</th>
<th>Simplified Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbiting scroll</td>
<td>Fixed thrust plate</td>
</tr>
<tr>
<td>Fixed scroll</td>
<td>Orbiting plate</td>
</tr>
</tbody>
</table>

*Equal friction area with same outer radius*

#### Scroll Compressor

- **Fixed plate**
- **Orbiting plate**
- **High pressure**
- **Low pressure**
The purpose of this study is to provide further experimental verification of the theoretical prediction for optimal design guidelines of the thrust slide-bearing in the scroll compressors.
A. Mixed Lubrication

A-1) Oil film pressure & force

Average Reynolds equation for rough surfaces by Patir & Cheng

\[
\frac{1}{R} \frac{\partial}{\partial R} \left( \phi RH^3 \frac{\partial P}{\partial R} \right) + \frac{1}{R} \frac{\partial}{\partial \theta} \left( \phi H^3 \frac{\partial P}{\partial \theta} \right) = \lambda \left( \frac{1}{R} \frac{\partial}{\partial R} \left( \overline{H} \cos(\theta - \Theta) \right) - \frac{\partial}{\partial \theta} \left( \overline{H} \sin(\theta - \Theta) \right) \right) + \lambda \sigma \left( \frac{1}{R} \frac{\partial}{\partial R} \left( \overline{\varphi_s} R \cos(\theta - \Theta) \right) - \frac{\partial}{\partial \theta} \left( \overline{\varphi_s} \sin(\theta - \Theta) \right) \right) + \sigma_s \frac{\partial \overline{H}_f}{\partial \tau_r}
\]

A-2) Solid contact force & frictional force

Solid contact theory by Greenwood & Williamson

\[
\alpha'(r, \theta) = \frac{dA}{rd\theta dr} = \pi \eta \beta \sigma \int_{H_r}^{\infty} (s - H_r) \phi'(s) ds
\]

B. Thrust Plate attitude

Equilibrium equations of forces & moments

\[
-mh_{\text{th}} + F_{\text{pl}} + F_{\text{oil}} + F_{\text{sc}} - F_s - F_{\text{po}} = 0
\]

\[
-L_x + \iint p(r, \theta) \cdot r \sin \theta \cdot r dr d\theta + \iint \alpha'(r, \theta) \cdot p_c \cdot r \sin \theta \cdot r dr d\theta - L_{\text{piv}} \cdot F_j \sin \Theta = 0
\]

\[
-L_y - \iint p(r, \theta) \cdot r \cos \Theta \cdot r dr d\theta - \iint \alpha'(r, \theta) \cdot p_c \cdot r \cos \Theta \cdot r dr d\theta + L_{\text{piv}} \cdot F_j \cos \Theta = 0
\]
Analytical Conditions

- Axial load: 600 N
- Gas thrust force: 2544 N
- Total thrust force: 3144 N
- Orbital speed: 300~6000 rpm
- Orbiting radius: 3.0 mm
- Wedge angle: 0.0048°

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer radius $r_o$</td>
<td>36~90mm</td>
</tr>
<tr>
<td>Inner radius $r_i$</td>
<td>30mm</td>
</tr>
<tr>
<td>Radius ratio $r$</td>
<td>1.2~3.0</td>
</tr>
<tr>
<td>Outer pressure $P_{out}$</td>
<td>1.1 MPa</td>
</tr>
<tr>
<td>Inner pressure $P_{in}$</td>
<td>0.5 MPa</td>
</tr>
<tr>
<td>Pressure difference $\Delta P$</td>
<td>0.6 MPa</td>
</tr>
<tr>
<td>Axial load $F_s$</td>
<td>600 N</td>
</tr>
<tr>
<td>Gas thrust force $F_p$</td>
<td>2544 N</td>
</tr>
<tr>
<td>Total thrust force $F_t$</td>
<td>3144 N</td>
</tr>
<tr>
<td>Orbital speed</td>
<td>300~6000 rpm</td>
</tr>
<tr>
<td>Orbiting radius</td>
<td>3.0 mm</td>
</tr>
<tr>
<td>Wedge angle $\alpha$</td>
<td>0.0048° degree</td>
</tr>
</tbody>
</table>
Theoretical Lubrication Analysis of Thrust Slide Bearing

Theoretical Results

Orbiting Speed of 3600rpm

Exhibiting minimum at certain $\gamma$

The value of friction power loss at $\gamma = 2.08$ is about 80% lower than conventional model.
Objectives

The purpose of this study is to provide further experimental verification of the theoretical prediction for optimal design guideline of the thrust slide-bearing in the scroll compressor.

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Experimental Lubrication Test to Verify Theoretical Results

Experimental conditions

- **Axial load**: 600 N
- **Higher pressure space**: 1.1MPa
- **Lower pressure space**: 0.5MPa
- **Orbital speed**: 1200~6000rpm
- **Orbiting radius**: 3.0mm
- **Refrigerant oil**: RB68A
- **Refrigerant**: R410A

**Table:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer radius $r_o$</td>
<td>42~66mm</td>
</tr>
<tr>
<td>Inner radius $r_i$</td>
<td>30mm</td>
</tr>
<tr>
<td>Radius ratio $r$</td>
<td>1.4~2.2</td>
</tr>
<tr>
<td>Wedge angle $\alpha$</td>
<td>0.0048 degree</td>
</tr>
<tr>
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<td>1.1MPa</td>
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<td>Axial load $F_s$</td>
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<td>3144 N</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Fixed thrust plate**: Thickness of thrust plate 10.4mm, 0.5mm
- **Crank shaft**: Outer radius varied
- **Pivot bearing**
- **Orbiting thrust plate**: Outer radius 42~66mm, Inner radius 30mm, Radius ratio 1.4~2.2, Wedge angle $\alpha$ 0.0048 degree
- **Higher pressure**: 1.1MPa
- **Lower pressure**: 0.5MPa
- **Axial load**: 600 N
- **Gas thrust force**: 2544 N
- **Total thrust force**: 3144 N
- **Orbital speed**: 1200~6000rpm
- **Orbiting radius**: 3.0mm
- **Refrigerant oil**: RB68A
- **Refrigerant**: R410A
Experimental Lubrication Test to Verify Theoretical Results

**Tribo-tester for Thrust-Slide Bearing**

- Pressure vessel
- Screw
- Thrust load spring
- Tank
- Heater
- Control valve of $\Delta P$
- Thrust load shaft
- Axial load $F_s: 600N$
- Strain gauges
- Positioning thrust shaft
- Pivot thrust bearing
- Fixed thrust plate
- Orbiting thrust plate
- Refrigerant oil
- Gas thrust force $F_p: 2544N$
- Friction force $F_f: 3144N$
- Mechanical seal
- Driven shaft
- Shaft coupling
- Crank shaft
- Mechanical seal
Experimental Lubrication Test to Verify Theoretical Results

Adjustment of Load

- Strain gauge
- Axial load
- Thrust spring
- Positioning thrust shaft
Measurement of Friction Force

Positioning thrust shaft
Strain gauge
Ball slide bush
Strain gauge
Positioning thrust shaft
Friction force $F_f$
Experimental Lubrication Test to Verify Theoretical Results

Comparison of experimental results and theoretical results

![Graph showing friction force versus orbiting speed for different lubrication tests at various orbiting speeds and lubrication parameters. The graph includes points marked with symbols indicating the friction force and orbiting speed for different conditions.](image-url)
The measured data agree well with the theoretical results.
Experimental Lubrication Test to Verify Theoretical Results

Comparison of theoretical and experimental results

Drastic reduction of friction power loss with increasing radius ratio.
The purpose of this study is to provide further experimental verification of the theoretical prediction for optimal design guidelines of the thrust slide-bearing in the scroll compressors.

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Conclusions

- The present experimental study has entirely confirmed the theoretical predictions.
- The friction power loss at the thrust slide-bearing can be decreased by about 80%, compared with that for the conventional design with $\gamma = 1.4$.

This study provides the optimal performance design guidelines in lubrication for the thrust slide-bearings in scroll compressors.

$\gamma = 1.8$ is recommended at least!