Numerical Analysis on the Oil Pumping Process for Reciprocating Compressors Considering Biphasic Flow

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Summary

• Embraco Overview
• Design to High Efficiency Compressors
• Oil Supply System for Reciprocating Compressors
• CFD 3D Simulation with ICEM/CFX
• Numerical and Experimental Results
• Final Remarks
Company Profile

- Market and Technological Leader in Hermetic Compressors for Refrigeration;
- It offers complete cooling solutions in the development of innovative and high performance products for the commercial and household refrigeration segments;
- Almost 10 thousand employees worldwide;

Mission: "Provide innovative solutions for a better quality of life".
World Presence
The Products

A wide range of products for all your needs.

Cooling Solutions
Design to high efficiency compressors

Improvements on the:

Mechanism

Manifold

Electric motor

High Efficiency

Assure:

- Low noise
- Quality and Reliability
- Low costs

Mechanical Power Losses

Lubrication

support

It is very important to reliability and high efficiency in refrigeration compressors.
Oil Supply System for Reciprocating Compressors

- The lubricant oil is speed up by the centrifugal force until the secondary bearing, then it is carried mechanically by the lubrication groove.

... and about the pumping head?
Oil Supply System for Reciprocating Compressors

- Modeling the simplified problem...

\[ dp = \frac{\partial p}{\partial r} dr + \frac{\partial p}{\partial z} dz \]

\[ p - p_1 = \frac{\rho \omega^2}{2} (r^2 - r_1^2) - \rho g (z - z_1) \]

\[ z = h_1 + \frac{(\omega r)^2}{2g} \]

where,

\[ h_1 = h_0 - \frac{(\omega R)^2}{4g} \]
Oil Supply System for Reciprocating Compressors

• and introducing a bottom hole...

\[ \rho \left( \frac{\partial u_r}{\partial t} + u_r \frac{\partial u_r}{\partial r} + \frac{u_\theta}{r} \frac{\partial u_r}{\partial \theta} + u_z \frac{\partial u_r}{\partial z} - \frac{u_\theta^2}{r} \right) = -\frac{\partial p}{\partial r} + \mu \left[ \frac{1}{r} \frac{\partial}{\partial r} \left( u_r \frac{\partial u_r}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 u_r}{\partial \theta^2} + \frac{\partial^2 u_r}{\partial z^2} - \frac{u_r}{r^2} \frac{\partial u_\theta}{\partial \theta} \right] + \rho g_r \]

The open area of the pump’s orifice is unable to support the pumping pressure. So, the oil flows down through the hole.

\[ P = \frac{\rho}{2} (r \cdot \omega)^2 - \frac{\rho}{4} (r_0 \cdot \omega)^2 \]

• “The pressure drop in the orifice can be determined by taking into account of inflow and outflow through the hole”. (Itoh, 1992)
Oil Supply System for Reciprocating Compressors

- The main variables at mechanical kit that influences in the pumping head are:
  - Inlet and outlet diameter;
  - Blade presence;
  - Oil viscosity;
  - Shaft speed;
  - Lubrication groove and orifices;
  - Oil pump imersion;
  - Geometric deviations

Ex.: concentricity between pump and rotation axis
Meshing in the ICEM:

- Easier to generate the interface domains and control the quality mesh.
- Tetraedric mesh + prisms (near the wall to increase the resolution).
Some options to input for the CFX analysis:

- Transient analysis
- Biphasic flow (oil based water + air)
- Time simulation 2s (step 0.01s)
- Buoyancy model
- Homogeneous model for multiphase and heat transfer
- Laminar flow
- Imersion 10mm
- Angular speed 3000rpm
and to raise the oil...

1. To rotate the Pump’s walls
   - The geometry must be axisymmetric
     - It does not support eccentric pump
2. To rotate the inside domain
3. To deform the mesh (not analyzed)
CFD 3D Simulation with ICEM/CFX

Mesh evaluation:

![Graph showing outlet flow over time step for different mesh types]
CFD 3D Simulation with ICEM/CFX

- Transient flow behavior

Initial time

Time step 5

Time step 50

Time step 200

Link to movie
Numerical Results

➢ Drives for the simulation

• Evaluate the oil flow sensitivity relative to the pump variables:
  • Outlet diameter
  • Inlet diameter
  • Blade presence
Experimental Test

- Bench Test:
  - The crankshaft rotation is controlled by an inverter.
  - The oil flow is evaluated by infrared sensors. It calculates the time to the oil speed up in a known volume.
Numerical Results:

- Blade evaluation:

  - it increases the momentum for the fluid.
Numerical Results:

- Outlet flow: 3 pump models:

This pump is able to provide good results, but is hard to assure the concentricity between the bottom end and the rotation axis in the manufacturing process.
Numerical Results:

Outlet diameter evaluation:

Above upper value (Outlet +0.4mm) the outflow is insensitive to increase the outlet diameter.
Numerical Results:

- Inlet diameter evaluation:

The relation between the inlet diameter and the outlet flow is not linear:
- if the inlet is smaller, it constricts the flow;
- if it is greater, the pumping pressure drops due to the open area.

An optimum point must be found.
Experimental Results:

- Flow x Inlet x Outlet

- The statistical analysis of the experimental results shows the similar direction from numerical simulation.
Concluding remarks

• The sensitivity analysis for the oil supply process has been performed.

• The CFX/ICEM proven to be effective for this kind of application. It is a powerful tool since it allows time and costs reduction looking for the geometric variables and tolerances in the prototype evaluation.

• The CFX still provide others analysis on the flow behavior for this application like: use of the turbulence models, comparison between the different models to speed up the flow (domain motion, rotation wall, deformed mesh).
Concluding remarks

• The total time simulation could be optimized if the meshing was made in the Workbench.

• Next steps:
  – Evaluate the oil flow considering also the crankshaft’s constraints.
  – Work to optimize the mesh (simulation time).
Thank you for the attention!

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