CFD Simulation Motion Analysis of an Orbiting Scroll Bearing Hub

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Abstract There are major areas that need to be considered when creating a chamber model of a scroll compressor, including the motor and the compression process. Minor energy losses need to be modeled as well, such as bearing losses, line losses, heat losses, and windage losses. One of these windage losses is the orbiting scroll bearing hub that moves around inside the scroll compressor housing. Computational fluid dynamics (CFD) simulations were used to investigate the differences in power between different methods of motion. One of these motions is in a rotating frame of reference and the other is in an orbiting frame of reference. The orbiting frame of reference is the correct motion but modelling it in a rotating frame of reference is easier to set up and does not require an advanced user to create the orbiting motion. This study will provide power comparisons at one dynamic viscosity and at three different speeds. For this study it will be conducted in a single fluid of oil only.

Keywords Scroll compressor · CFD · Mesh motion

1 Introduction

There are many CFD tools available. For this study ANSYS CFX was used. The differences in power between using a rotating reference frame and an orbiting reference frame were investigated to make it easier for a casual user to simulate the analysis. An option available in CFX is to turn the domain into a rotating reference frame, making it much easier to setup and simulate a rotating frame of reference. Another advantage is the rotating reference frame can simulate the rotating motion much faster than the orbiting reference frame. For the orbiting reference frame, a mesh motion model and a set of velocity terms were applied to the orbiting scroll bearing hub. The issue with using the rotating reference frame is that it is not the

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motion of the orbiting scroll, but how much difference there is between the two methods. That is the focus of this paper. To make the simulations easier, they were run as an oil-only analysis.

2 Simulation Setup

The setup for these simulations is similar to the analysis when modelling the scroll oil pump analysis Branch [1] in 2015. The rotating and orbiting motion simulations were analyzed to determine the power differences between the two movement processes. The torque and power of the orbiting scroll bearing hub was found using the same technique as Branch [2] in 2014.

2.1 Geometry Preparation

Figure 1 explains the solid parts used to setup the negatives for the simulation. It also shows the fluid inlet. Figure 2 shows the negative used for these simulations.

Figure 3 shows a meshed cross section of the simulation. The inside domains were meshed as a hexahedral meshes where the outside domain was meshed as a tetrahedral mesh. The total mesh size is 3.7 million nodes.

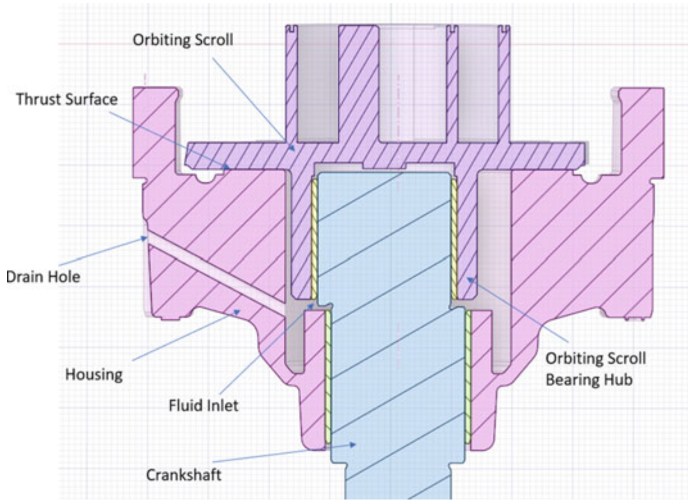

Fig. 1 Simulation geometry

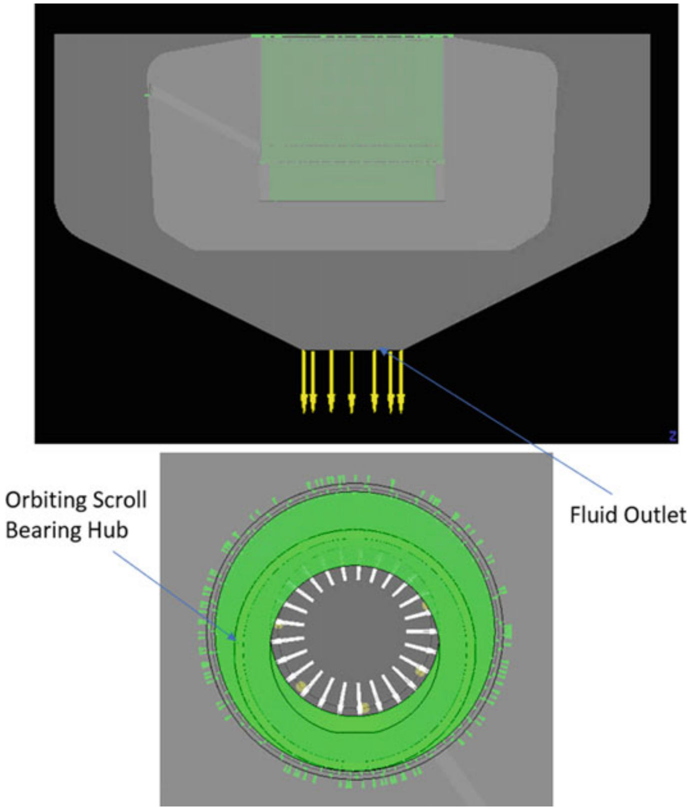

Fig. 2 CFD simulation setup

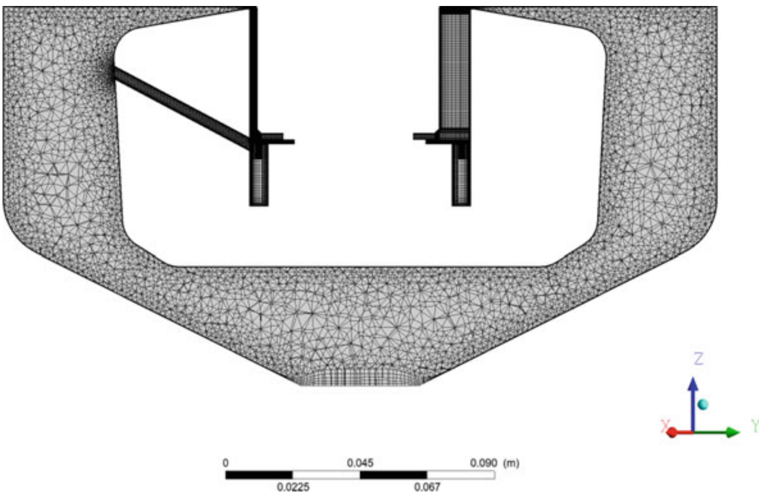

Fig. 3 Simulation cross section showing the mesh

2.2 CFD Setup

- ANSYS CFX Version V2022R1 was used for the CFD Analysis
- Transient Simulation—one degree of movement per time step
- Heat Transfer method used = Isothermal
    - Oil Temperature = 187.3 °F
- Simulation Initial Static Pressure = 88.94 psia
    - Outlet Static Pressure = 87.94 psia
- Turbulence Model = SST
- All walls are adiabatic
- Compressor rotational speed = 900, 3600, 7200 rev/min
- Fluid = RL32H Oil
- Oil Viscosity = 14 cP

The simulation was set up in three domains. There is the outside stationary domain which connects the thrust surface, angled pipe, and the outlet together. The stationary domain has the angled pipe and the thrust surface exit. It also connects the moving domain to the outside stationary domain. The inside domain is the moving domain which contains the inlet and the orbiting scroll bearing hub. The moving reference frame was created so it could apply a rotating reference frame and an orbiting motion. To aid in the motion, the moving domain was created so it can rotate about the global z-axis. The moving reference frame is highlighted in green in Fig. 2. To create the orbiting motion, a mesh motion process was used. Then an orbiting velocity was applied on the orbiting scroll bearing hub.

Rotating Reference Frame

- Orbiting Scroll Bearing Hub
    - Motion is rotating.
    - Velocity profile is rotating.

Orbiting Reference Frame

- Orbiting Scroll Bearing Hub
    - Motion is rotating.
    - Velocity profile is orbiting.

The orbiting velocities are shown below.

Table 1 Simulation oil flow rates

RPM	900	3600	7200
Oil Flow rate (kg/s)	0.004645	0.020845	0.04169

$$V_x = -VTheta \times sin(oa + dTheta) \quad (1)$$

$$V_y = VTheta \times cos(oa + dTheta) \quad (2)$$

oa orbiting angle = Starting angle of the orbiting scroll
dTheta compressor rotational speed in rev/min × time
VTheta crank shaft throw (offset) × compressor speed in rev/min

The inlet to the simulations is an oil mass flow rate and is shown in Table 1. These were determined from a bearing flow model.

3 Results

The results will show the differences in velocity profiles of the orbiting scroll bearing hub between the rotating and orbiting simulations. The process used to evaluate the windage power of the simulations will be explained. Finally, the windage power differences are shown in Table 2 between the rotating and orbiting reference frames at various speeds.

Figure 4 shows the orbiting scroll bearing hub rotating motion which was taken from the 900 rev/min rotating simulation. Figure 5 shows the orbiting scroll bearing hub motion orbiting from the 900 rev/min orbiting simulation.

Instantaneous power was calculated by measuring the torque of the orbiting scroll bearing hub multiplied by the speed at every time step. Results were averaged over a full revolution to determine the power. The torque was obtained by offsetting the axis shown on Fig. 6 by the crank shaft throw times the force in the y-direction. Figure 6 shows locations at zero degrees and one hundred and eighty degrees where the instantaneous torque/power values were obtained.

Table 2 Orbiting scroll bearing hub power

Speed	Rotating	Orbiting
(rev/min)	Average Power (W)	
900	1.0	1.8
3600	39.8	69.6
7200	293.6	474.4

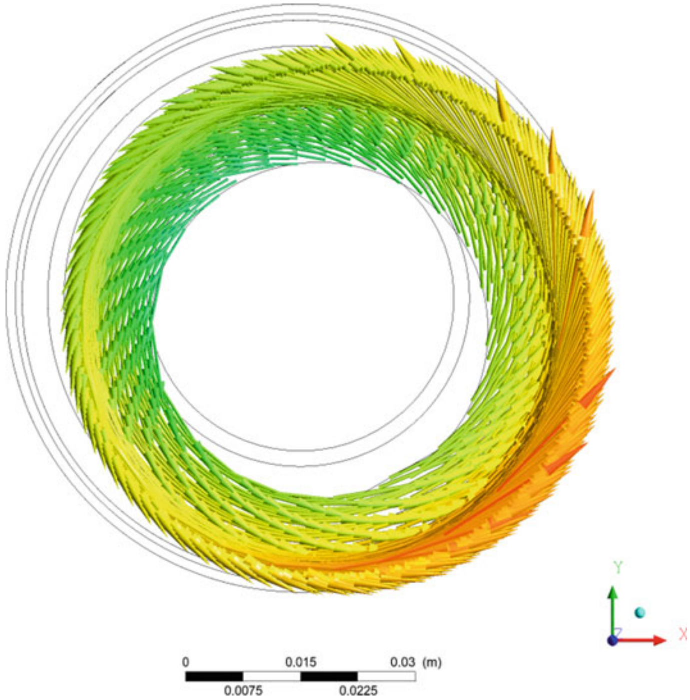

Fig. 4 Orbiting scroll bearing hub rotating motion

The orbiting power is the correct form of motion, and it was compared to the rotating motion to see how closely they compared. Table 2 shows the simulation power calculated for the orbiting scroll bearing hub at various speeds.

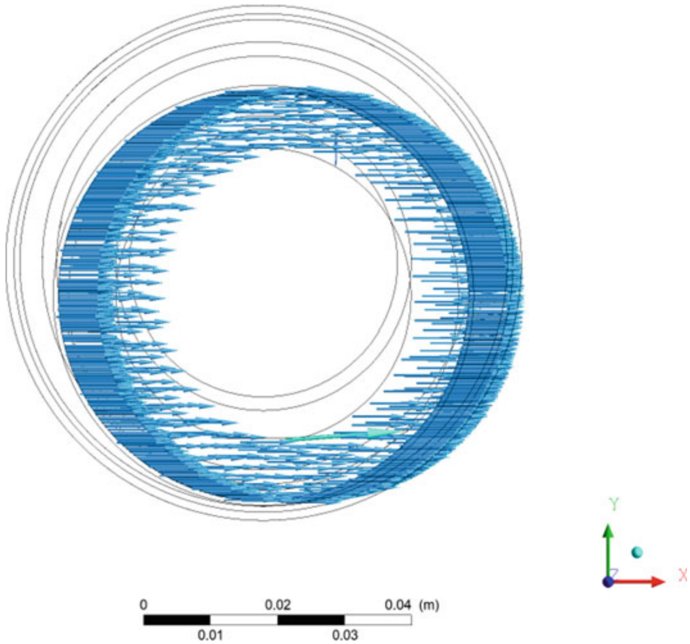

Fig. 5 Orbiting scroll bearing hub orbiting motion

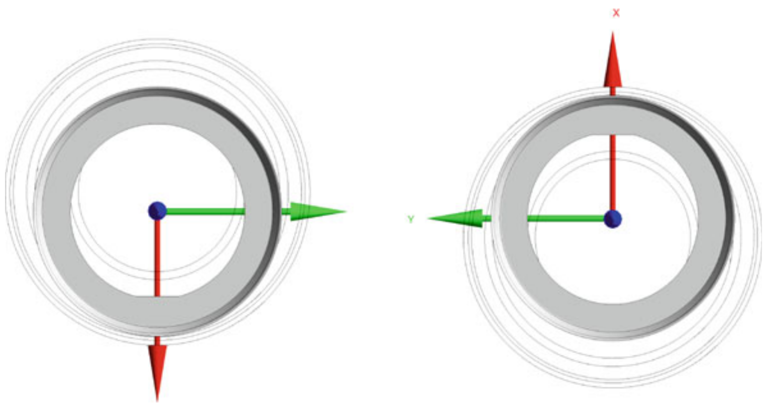

Fig. 6 Torque calculation process at 0° and 180°

4 Conclusion

Even though the rotating method is faster and easier to set up, the results were less accurate than the moving mesh orbiting movement. The next step will be to model this simulation as an oil/ refrigerant gas multiphase process using the moving mesh orbiting motion process.

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