Film Thickness and Flow Visualization Measurements in a Thrust Collar

NEW PROPOSAL

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Introduction

Integrally geared compressors (IGCs) offer higher thermal efficiency and a smaller footprint when compared to traditional single-shaft multistage centrifugal compressors [1]. The axial load produced from the impellers and the force from the geared connection create an axial load on the pinion shaft that must be balanced to ensure reliable operation. Thrust collars (TCs) provide a way to transmit the axial load from the pinion shaft to the bull gear (BG) shaft, on which resides a large diameter thrust bearing to react the total IGC thrust load. Increasing the power density of IGCs could expand their application range to higher flows and compressor ratios. However, the efficiency and capacity increase comes at a cost of additional load and higher speed requirements on the TCs.

The Turbomachinery Laboratory developed a test rig based on a typical IGC. Figure 1 details the thrust collar test facility (TCTF) which resembles a single-pinion IGC. The geometry of the shafts match that of a typical IGC. The rig does not include gears but uses two motors to spin each shaft at independent speeds. A pneumatic loader applies a load up to 7,000 N (80 bar unit load) on the pinion shaft, which is transmitted through the TC onto the bull gear (BG) shaft. The pinion and bull wheel shafts are independently controlled with VFDs and can spin up to 20,000 and 3,600 rpm, respectively. The TC is made of acrylic and has two windows which allow for visualization of the oil film. Figure 2 shows images captured from a high speed camera. The image on the left is a raw photo of the oil film, and shows cavitation occurring in the upper region of the oil film, and turbulence in the lower (entrance) region. The image on the right is a binary image that highlights the location of the cavitation and turbulence regions. Figures 2, 3, and 4 were taken at pinion speeds of 7,500 rpm and axial loads of 1,500 N (15.5 bar).

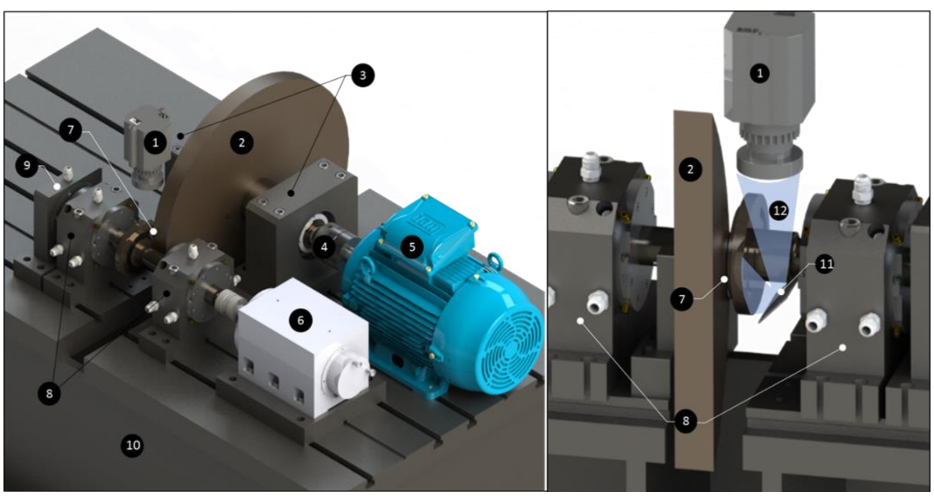

Figure 1: Solid model TC test facility showing main components and cut-view depicting high-speed optical set-up. (1) High speed camera, (2) Bull wheel, (3) BW shaft ball bearings, (4) jaw-type coupling, (5) Low speed motor, (6) High speed motor, (7) Transparent TC, (8) Hydrostatic bearings, (9) Pneumatic loader, (10) Bedplate, (11) Mirror, (12) Visualization path.

Figure 2 Overlap area between thrust collar and bull wheel highlighting locations of cavitation and turbulence

Proposed Work and Deliverables

Figure 3 shows the predicted load capacity versus minimum film thickness based on a finite element Reynolds equation solution. The figure shows that including elastic deformation decreases the load capacity of the TC. Figure 4 displays the film thickness of the TC, and shows that the location of the minimum film thickness. For the rigid model, the minimum film thickness occurs along the entire center-line of the overlap area, but when including elastic deformation, the minimum occurs at the edges of the overlap, on the border of the disks (edge thinning).

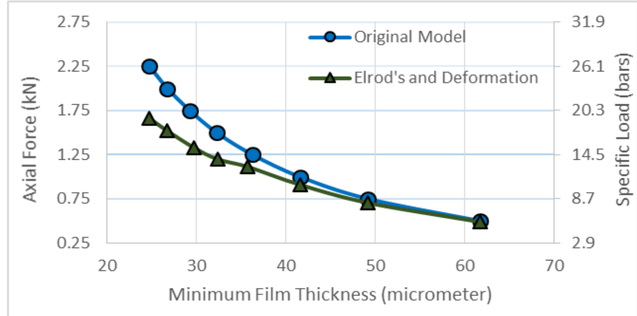

Figure 3 Predicted load capacity versus minimum film thickness for a rigid and elastic model, showing when elasticity becomes

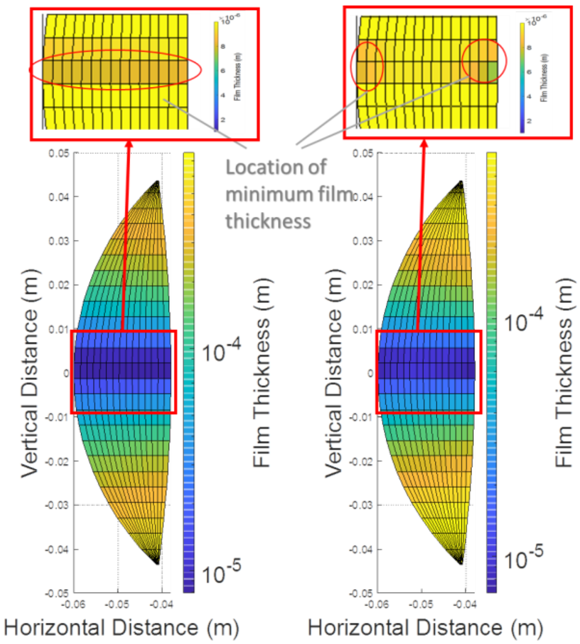

Figure 4. Predicted film thickness for a rigid (left) and elastic (right) model, showing location of minimum film thickness

The proposed testing will utilize a confocal interferometer in conduction with the transparent TC to measure the film thickness for a range of loads and speeds. The interferometer has a high resolution (50 nanometers), is oil-proof, and will be able to map the entire oil film. Testing will start at a given speed, and the load will be increased steadily until the film collapses, or the load is at its maximum capacity.

The test results will determine the location of the minimum film thickness, and if edge thinning is occurring. The test results will be compared the in-house code to determine the accuracy of the load capacity predictions. The results will also be compared to a computational fluid dynamics model. After load testing is complete, starvation testing will begin. The high speed camera and interferometer will record the oil film at reduced oil supply flowrates. The testing will determine what is the minimum oil supply flow rate is before scoring occurs.

The testing will aide in the design and modeling of TCs and ultimately could lead to an increase of the total load capacity.

Budget

Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 3,127
Tuition and fees	$ 17,186
Test supplies (optical equipment)	$ 3,287
Total	$ 50,000

References

[1] Wygant, K., Bygrave, J., Bosen, W., and Pelton, R., 2016, "Tutorial on the Application and Design of Integrally Geared Compressors," Proceedings of the First Asia Turbomachinery and Pump Symposium, Texas A&M University, College Station, TX.