

Project Overview

AirFoil Dynamics has been tasked to design a gas thrust bearing test rig capable of sustaining 20 bar of pressure while operating at 70,000 rpm, for the Turbomachinery and Energy Systems Laboratory (TESLAB) for research purposes here at UTA. AirFoil Dynamics will deliver complete engineering design and verification using various software, interactive CAD models of the entire assembly, and detailed engineering drawings in alignment with the latest GD&T standards.

Verification of design function and operation will utilize several types of analysis such as fluid structure interaction, rotor dynamics and component interfacing. Additionally, Implementation of sensors will provide data on the location and temperature of the drive-shaft, load capacity of the thrust bearings and their associated power loss across varying speeds during operation.

The overall intent of this product is to validate existing and future gas foil bearing models owned by TESLAB and provide data on gas bearings in high pressure conditions. With the goal of improving the modeling these bearings application of them in real-world systems.

Background

- Gas foil bearings are a type of bearing that are typically used for high-speed Turbomachinery.
- Unlike most typical Journal Bearings which operate using a thin oil film, gas foil bearings instead use a thin film of air or other gas allowing for oil-free lubrication systems.

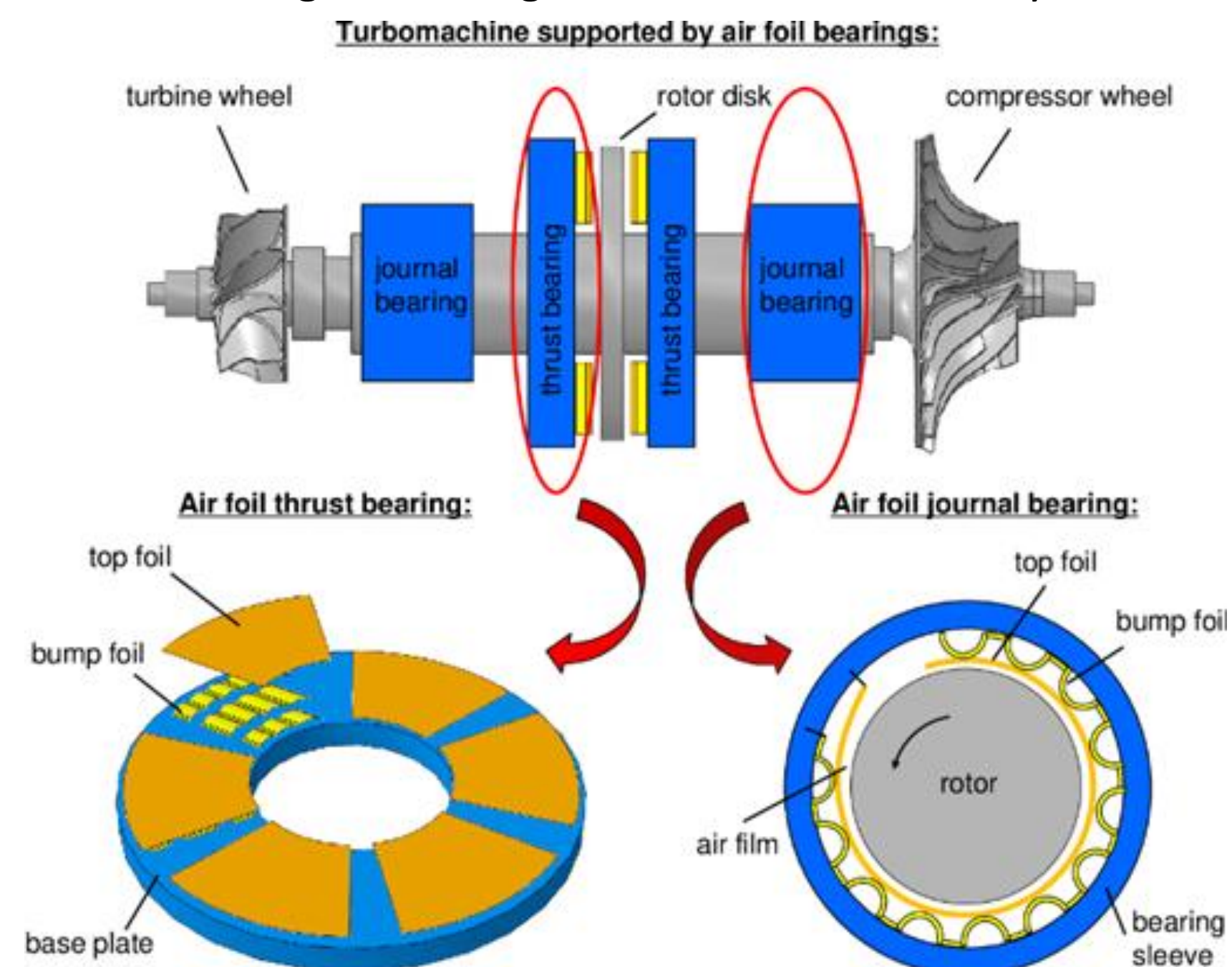


Figure 1. Journal VS Thrust Bearing Diagram

- The Figure above displays the geometry of air foil bearings used in most turbomachinery applications.
- Some applications include refrigerant turbo compressors used for heat pumps and industrial HVAC systems, and turbo expanders for energy recovery systems.

Analysis

Hydrostatic Thrust Bearing:

Using Gas Bearing Code developed in TESLAB, we were able to solve for:

- the pressure distribution across thrust bearing to ensure the test volume went to 20 bar
- the load capacity to be 2180N, to ensure it exceeded twice the applied force
- This will ensure that the thrust runner does not collide with the housing and is able to support the applied load
- The number of orifices, orifice diameter, operating pressure, and nominal clearance must be defined

Rotor-dynamic Analysis:

- To verify the shaft stability, the drive shaft was discretized, and mass properties used as inputs into commercial rotor dynamic software.
- The critical speed was found to be 106krpm, giving a 51% critical speed margin over the operating speed of 70krpm. [standard margin of 10-20%]
- We validated the discretized model by having a max error of 5% in mass and moment of inertia values between the software and our solid model.

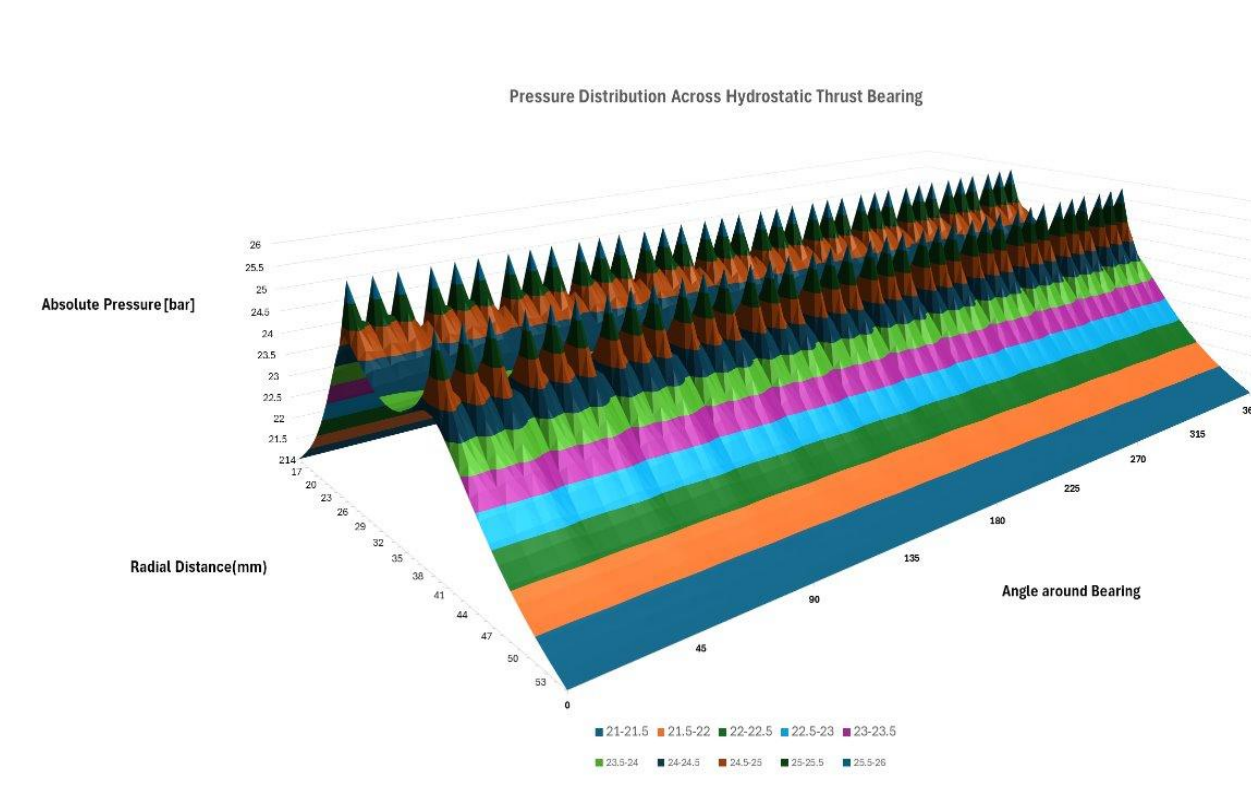


Figure 2. Hydrostatic Bearing Pressure Distribution

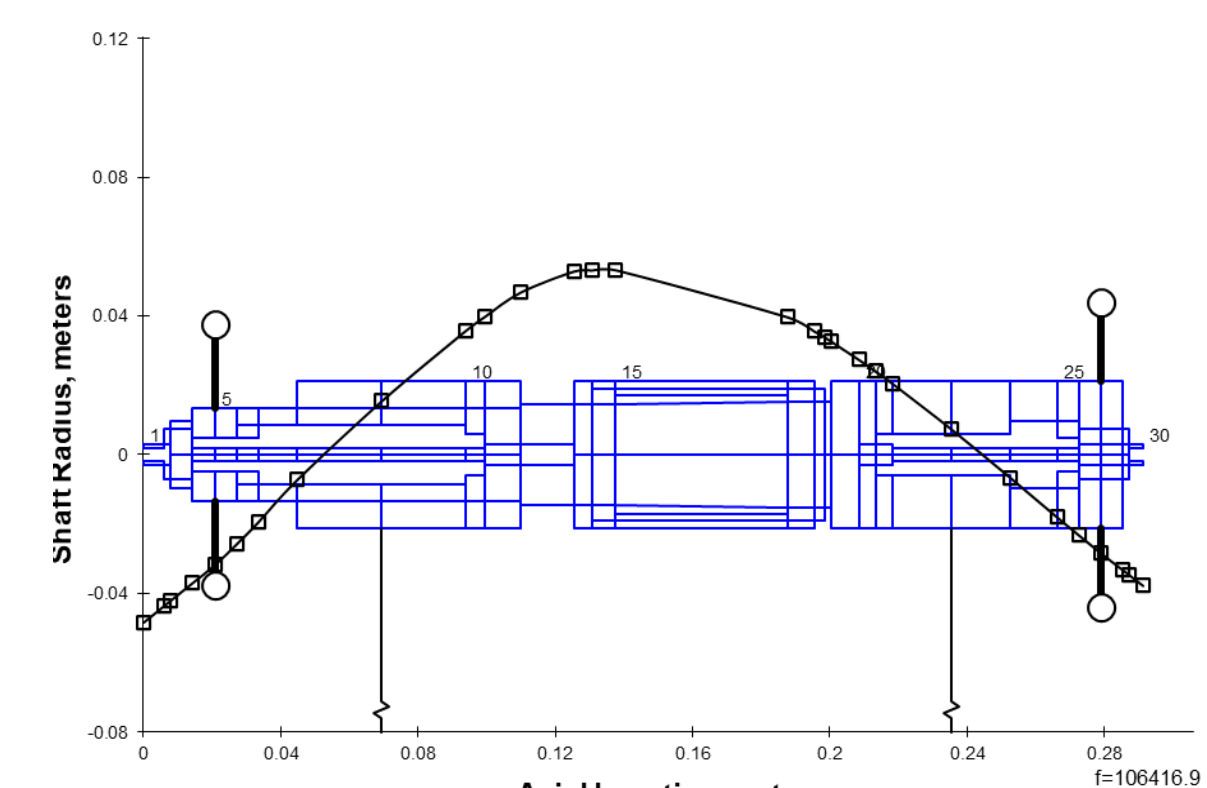


Figure 3. Drive Shaft Bending Mode

Simulation Process

- Several sub-systems of the test rig were simulated including the water jacket cooling system for the motor, and radial bearing power loss.

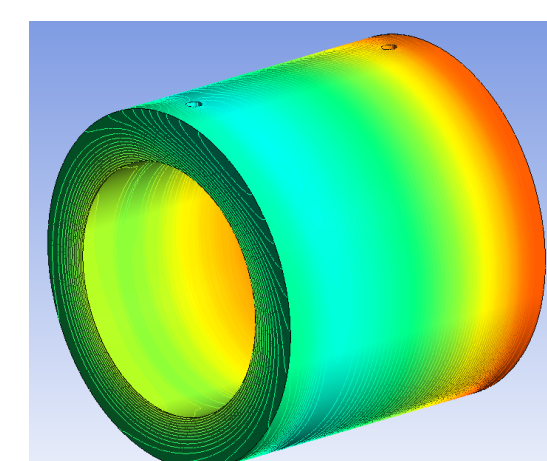


Figure 4. Temperature in cooling system.

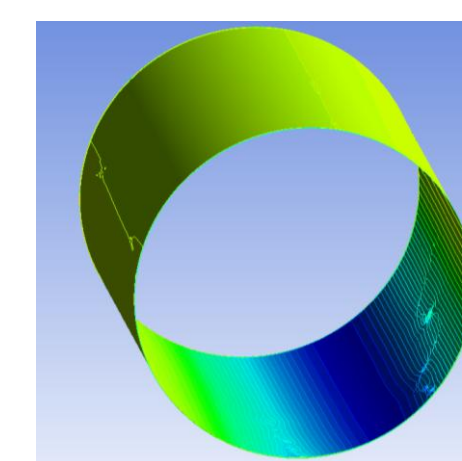


Figure 5. Shear pressure on radial bearing.

- A system level simulation of the temperature distribution was used to ensure critical components in the motor and sensors did not exceed allowable temperatures.
- Simplifications were made to geometry to reduce setup time.
- Energy and mass conservation methods were used to calculate boundary conditions.

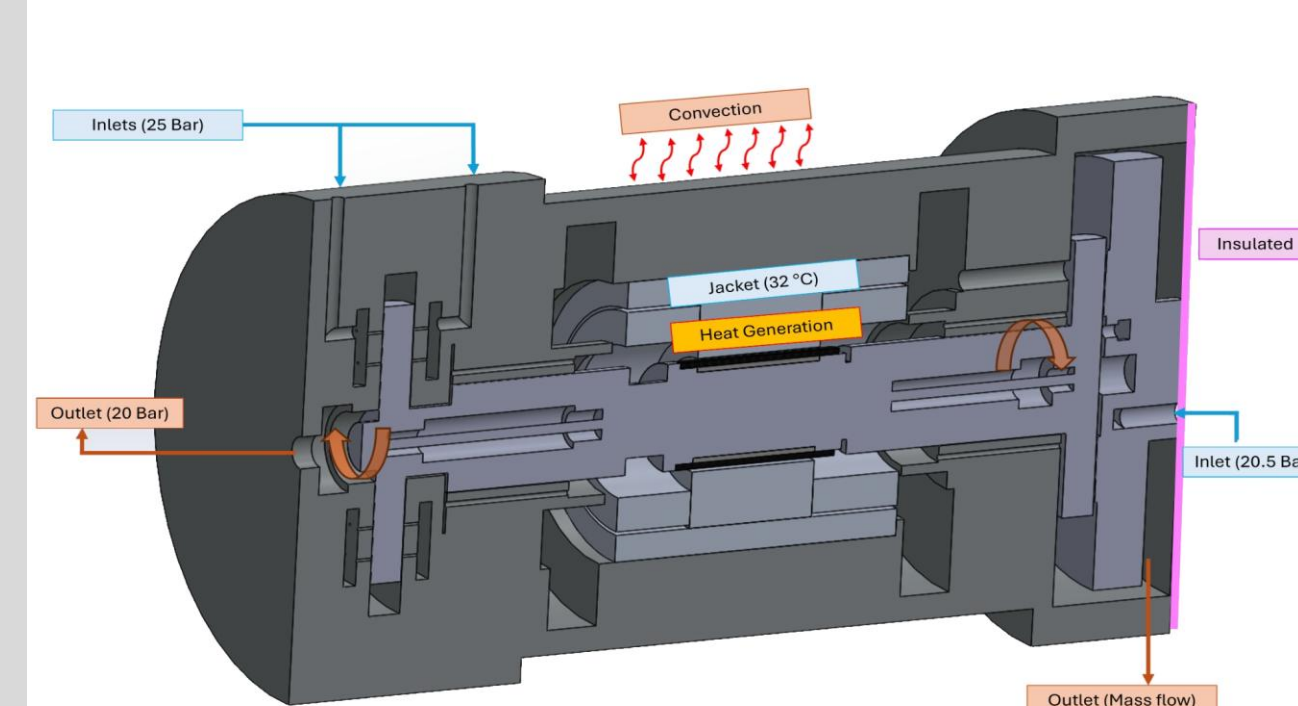


Figure 6. Boundary condition setup.

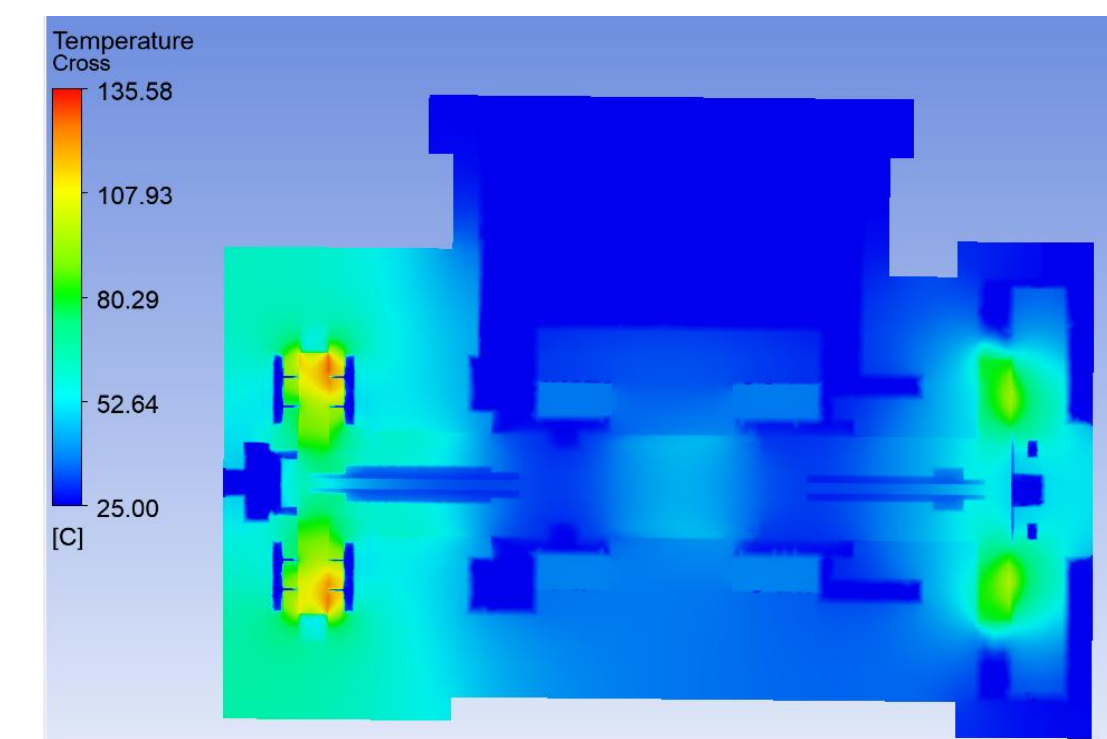


Figure 7. Temperature distribution

Conceptual Design

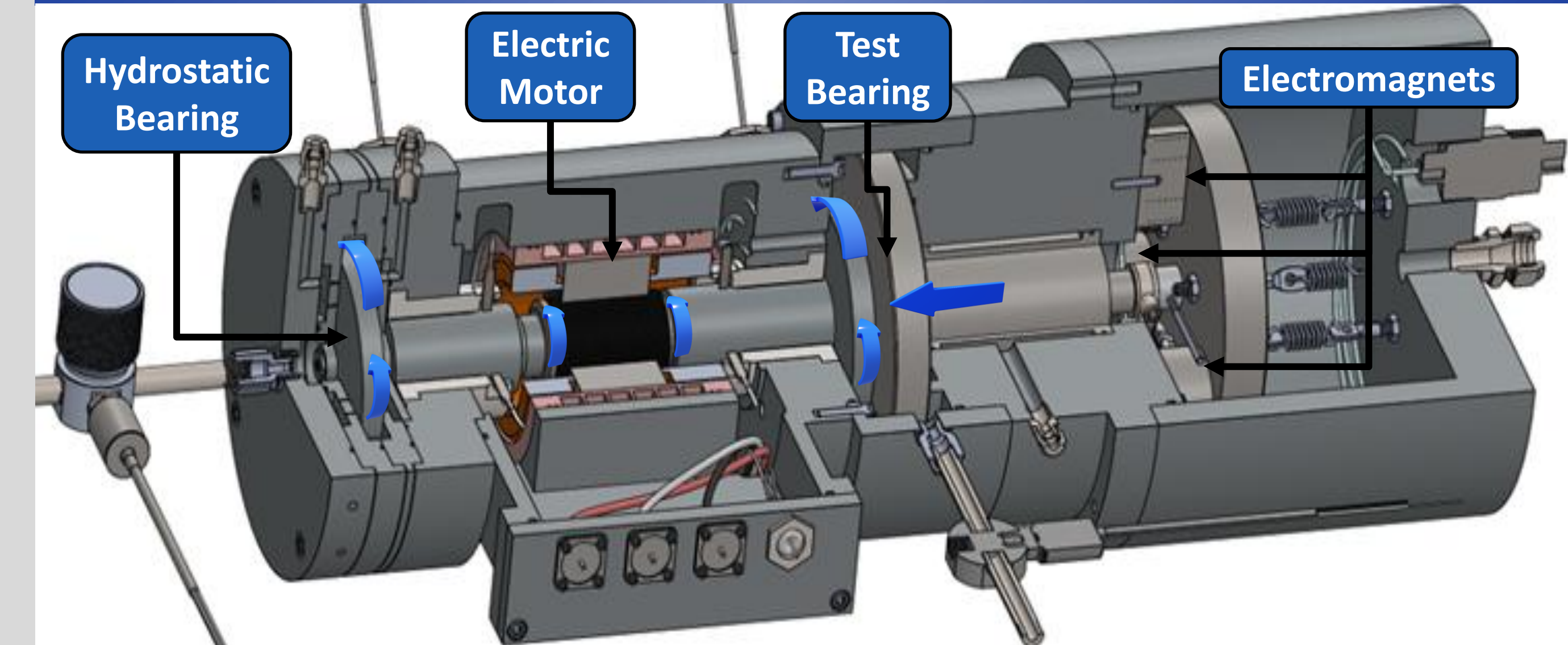


Figure 8. Complete Test Rig Cross View

Arrows display the rotation of the shaft and load application during use, and the main components of the rig are labeled as seen above.

Drive Shaft:

- The shaft was designed to ensure a high critical speed safety margin
- Radial bearing contact surfaces were increased to reduce shaft deflection
- Oil injection grooves were designed to allow for interference fit of Permanent Magnet sleeve over shaft during assembly
- Thrust runners for test and hydrostatic bearings are tension bolted into place

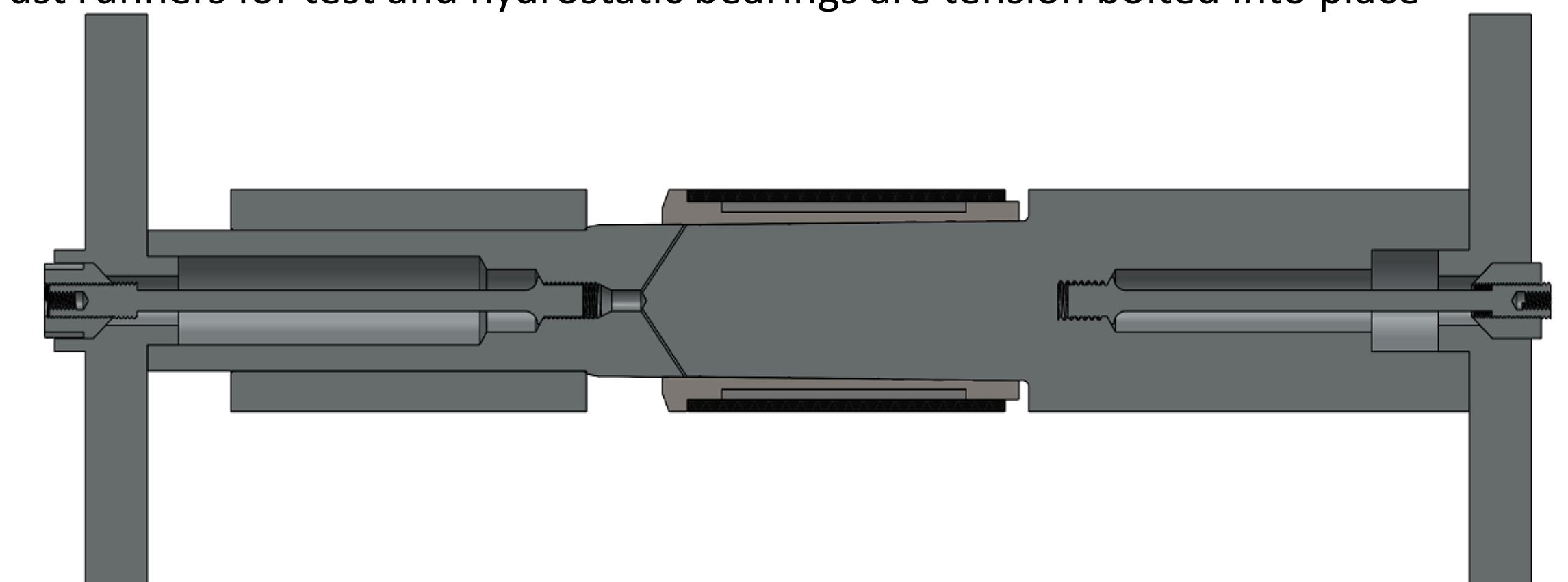


Figure 9. Drive Shaft Cross-Sectional View

Hydrostatic Bearing:

- Designed to support an axial load of 2000N on the shaft
- With a gas pressure of 25 bar, as demonstrated in the blue
- Spaced holes allow for the gas to be dispersed onto the thrust runner suspending it in air
- This supports the entire driveshaft allowing the test bearing to be measured during load application
- O-rings are specified around each section to ensure no pressure leakage and
- Pressure regulators control pressure to maintain target pressure, which is higher than the internal main chamber pressure of 20bar

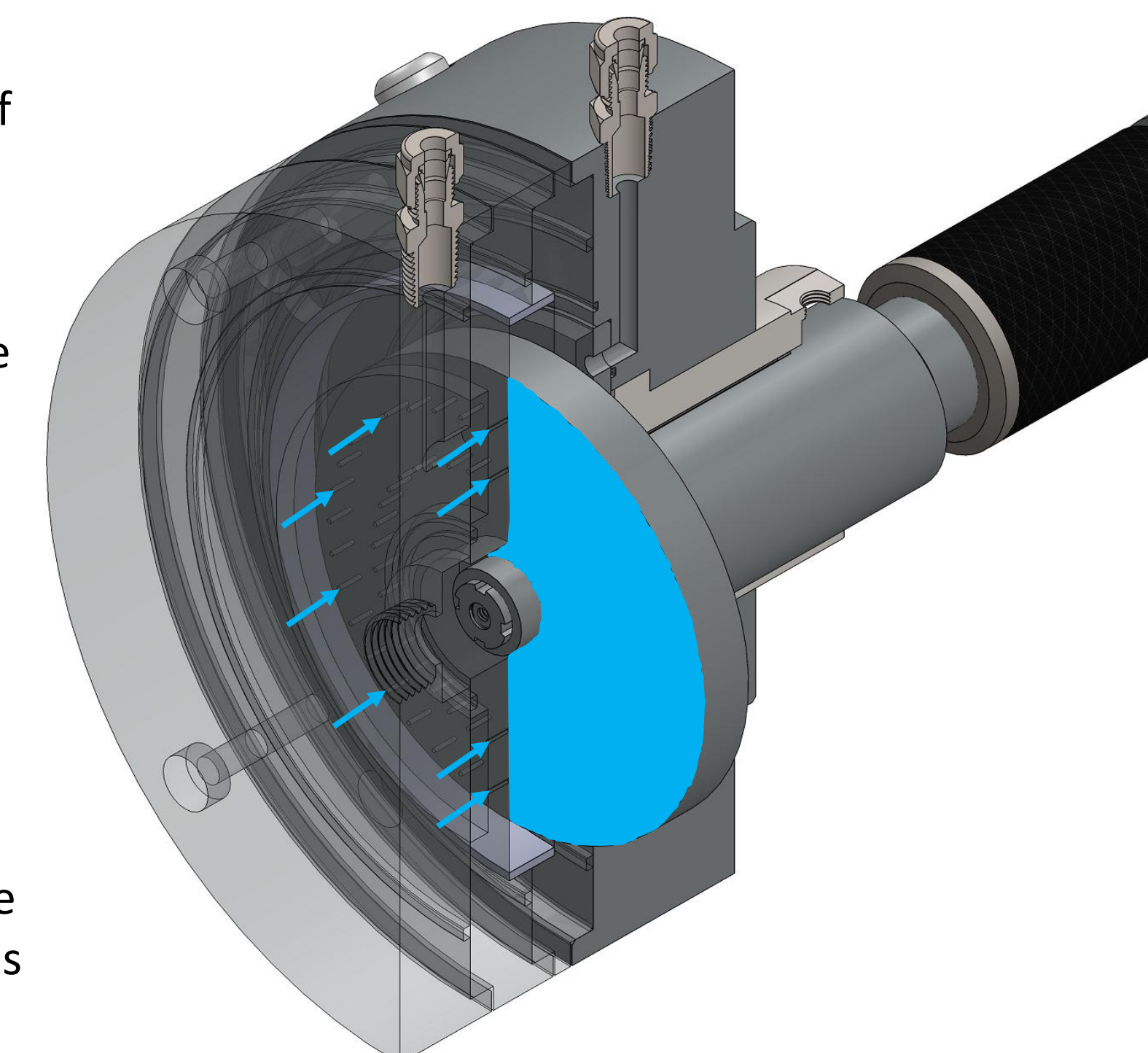


Figure 10. Hydrostatic Cross Isometric View

References

- Lehn, A., "Air foil thrust bearings: A thermo-elasto-hydrodynamic analysis," TU Darmstadt, 2017, Fig. 1.1: Components of a compliant air foil thrust bearing.