Machinery Health Monitoring and Component Testing using a Magnetic Bearing with an sCO_2 Turbomachine

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Supercritical CO_2 Power Cycles Symposium

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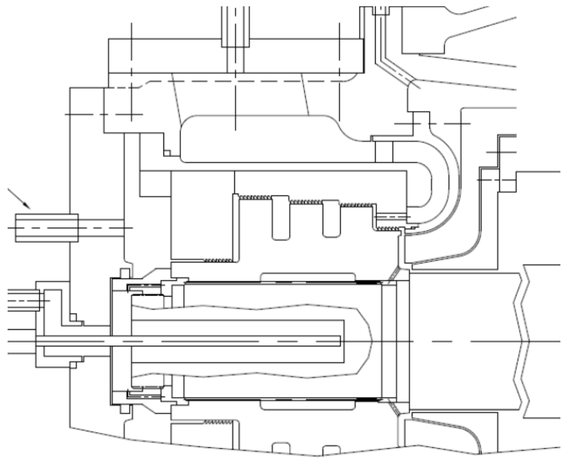
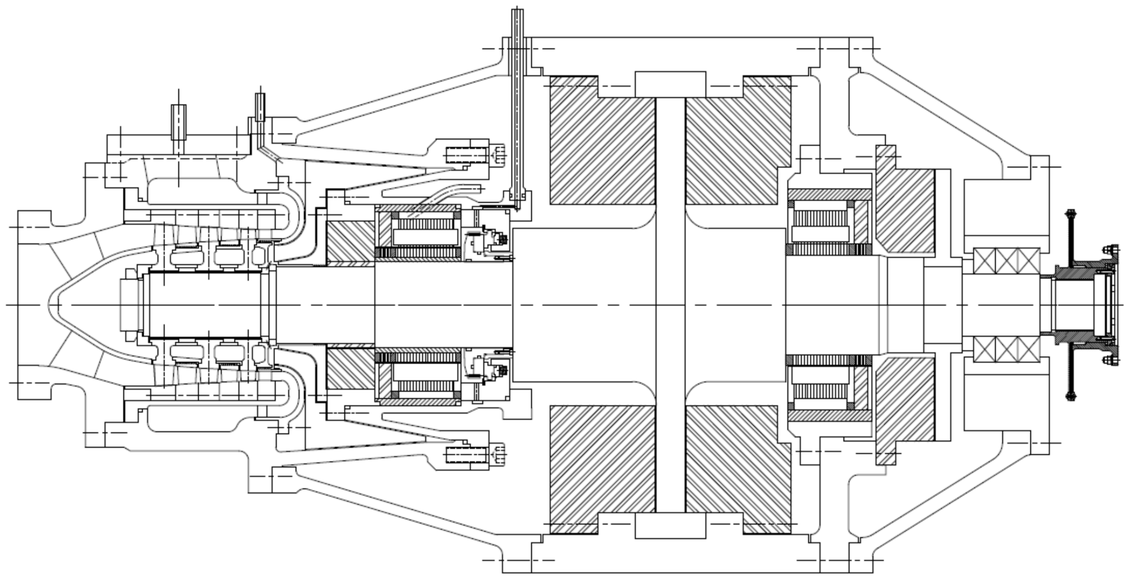
EXPERTS IN TURBOMACHINERY



Labyrinth Seal Test Apparatus



Magnetic Bearing Spindle

Supercritical Fluid Influences the Machine Design

- For the same power, the sCO_2 machinery is smaller and compact size can offer benefits.
- Smaller machines require higher speeds to meet the optimum efficiency point.
- Smaller machines have smaller shaft diameter.
- High temperature turbines must have thermal separation from the bearings and the containment seals. Thermal separation requires increased axial length for the shaft.
- High density fluids enable high pressure rise in a single stage.
- Interstage seals are important to reduce internal leakage in a machine. The pressure across each interstage seal is much greater in the sCO_2 machines.
- Better sealing means increased seal length. Longer labyrinth seals are required.
- Improved sealing with features that will minimize the destabilizing effects of the seal are an important design criteria.

Fluid Forces Within the Machine

- Rotordynamic stability is influenced by the fluid whirling within the seals, impellers, and balance pistons. Any component on the shaft that is surrounded by the working fluid is exposed to the fluid forces.
- The fluid forces are greater with higher density fluids. The established variables for modeling the aerodynamic loads due to whirling fluid include power, speed, fluid density, rotor diameter, and width.
- Fluid forces acting upon wider surfaces will produce greater total force. Longer seals will provide the wider surfaces.
- Rotors that are longer and smaller in diameter have more flexibility.
- Greater flexibility means the rotor will be more sensitive to strong whirling forces on the rotor components. These forces can dominate the vibration response of the machine and lead to machine failure.
- Operation of the power cycle will produce variable conditions to the turbomachines. Performance during controlled start-up and shut-down or an emergency event will create variable conditions. The heaters, recuperators, and coolers are sensitive to the process conditions. The compressor and turbine will operate across a wide range of the performance maps before the process settles into the optimum efficiency operating point. Changes to the heater and cooler input and management of the fluid inventory to the loop can affect the phase state of the fluid, which can have damaging results.

Component Level Testing and Real Time Monitoring with Magnetic Bearings

- Magnetic bearings are uniquely capable of measuring the loads they support. The magnetic bearing is an actuator and position sensor pair. The force applied to the bearing and the response to the force can be measured in real time.
- The magnetic bearing can be used for characterization of the turbine or compressor or any individual component, such as a process seal or interstage labyrinth seal.
- Aerodynamic forces from the seals or turbine rotors can be empirically obtained and used to create design tools for future machines. Predictions for rotordynamic stability will be improved.
- Axial thrust forces can be measured in real time. Steady and dynamic thrust forces can be very high in high density machines. Currently, the process used for the calculation has wide accuracy margins. Measurement of the loads at the off-design conditions in real operating machinery will be very valuable.

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