Design and Development of Passive Magnetic Bearings for High-Speed Turboexpander

Suraj K Behera, Jitesh Kumar, Ranjit Kumar Sahoo
National Institute of Technology, Rourkela, Rourkela 769008, Odisha (INDIA)

Introduction
The high-speed applications such as turboexpander uses aerodynamic gas bearing for contamination free system. The major issue with aerodynamic gas bearing is during the phase of starting and stopping the rotor. Above issue can be prevented by use of the passive magnetic bearing. This paper explains about design and development of passive magnetic bearing for the turboexpander rotating at 80,000 rpm. Two pairs of ring magnets using material Neodymium (NdFeB) alloy magnet of Grade N42 are simulated, and the distance between them is predicted to support the axial load. The two pairs of ring magnets are used in a turboexpander setup and tested their performance.

Anatomy of Turboexpander

Available Bearings for Turboexpander

Issues with Aerodynamic Gas Bearings

Design of Passive Magnetic Bearings

- Brake Compressor
- Rotor Ring
- Stator Ring
- Dynamic Seal
- Expansion Turbine

Method 1: Analytical

- The elemental magnetic force is expressed in below Equation [2]. Where J and S are the magnetic polarization of the rings and surface area respectively. The elemental forces between elements of surfaces A-D, C-B, and C-D is calculated using the similar notations.

\[ F_{A1B1} = \frac{J_1 J_2 S_{A1} S_{B1}}{4 \pi \mu_0 r_{A1B1}^3} F_{A1B1} \]

Method 2: Finite Element Software (FEMM)

Available Bearings for Turboexpander

Issues with Aerodynamic Gas Bearings

Design Data of the Ring Magnets

- Material: NdFeB, Grade N42
- Magnetic field: 1.4 Tesla

Pair 1 configuration
- \( R_{11} = 5 \text{ mm} \), \( R_{21} = 7.5 \text{ mm}\), \( L_{11} = 5 \text{ mm} \)
- \( R_{12} = 6.35 \text{ mm} \), \( R_{22} = 9.525 \text{ mm}\), \( L_{22} = 3.175 \text{ mm} \)

Pair 2 configuration
- \( R_{11} = 5 \text{ mm} \), \( R_{21} = 7.5 \text{ mm}\), \( L_{11} = 5 \text{ mm} \)
- \( R_{12} = 5 \text{ mm} \), \( R_{22} = 7.5 \text{ mm} \), \( L_{22} = 5 \text{ mm} \)

Axial Distance Vs. Repulsive Forces

Parts for Auxiliary Passive Magnetic Bearing

Vibration Signature Near Lower Journal Bearings

Conclusions
The central objective of above research work is to suggest a structured design and fabrication methodology for auxiliary passive magnet bearing. The developed passive magnetic bearings are found to be compact and reduce the friction during start and stop phase of the rotor of 2.64 N dead weight. The same methodology can be used in other high speed turbomachinery operating with aerodynamic bearings.

Reference