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

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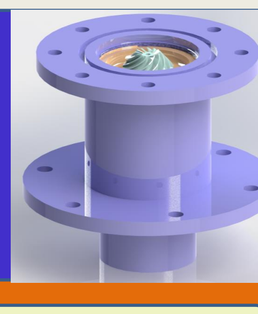
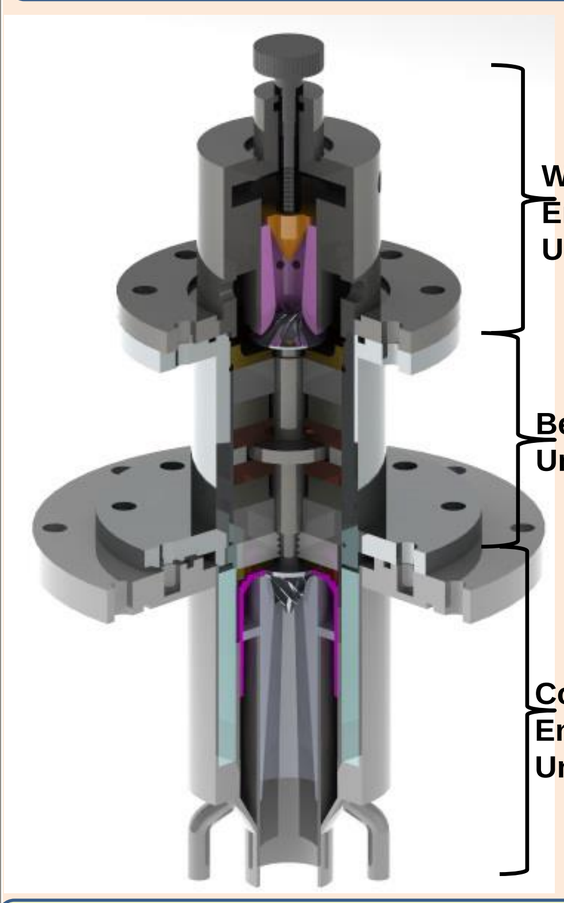


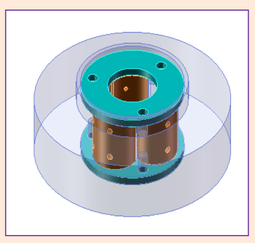
Introduction

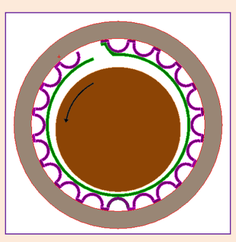
The high-speed applications such as turboexpander uses aerodynamic gas bearing for contamination free system. The major issue with aerodynamic gas bearing is during the phase of starting and stopping the rotor. Above issue can be prevented by use of the passive magnetic bearing. This paper explains about 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.

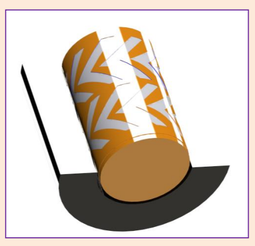
Anatomy of Turboexpander

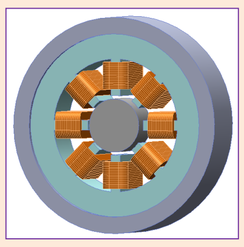


Available Bearings for Turboexpander


Tilting Pad


Gas Foil

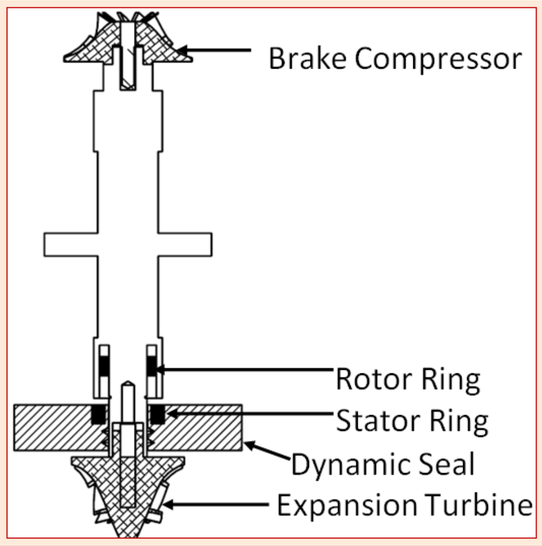

Herringbone


Active Magnetic

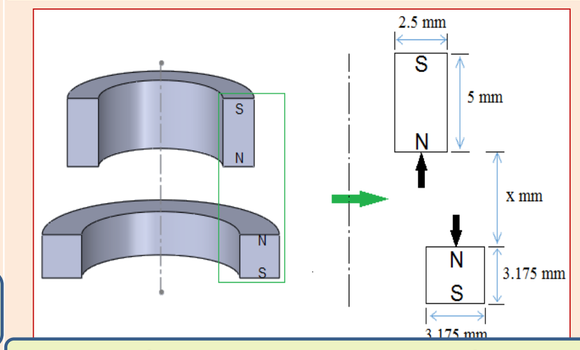
Issues with Aerodynamic Gas Bearings

- **Direct contact between rotor and bearings during start and stop of the machine.**

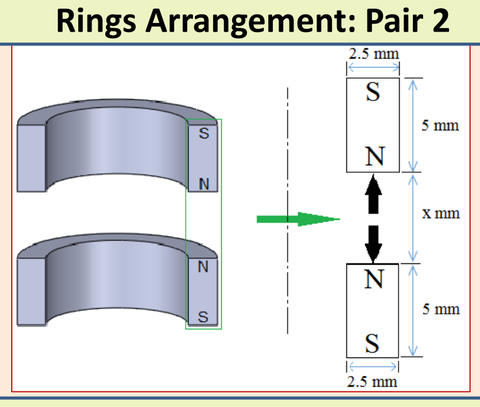
Design of Passive Magnetic Bearings



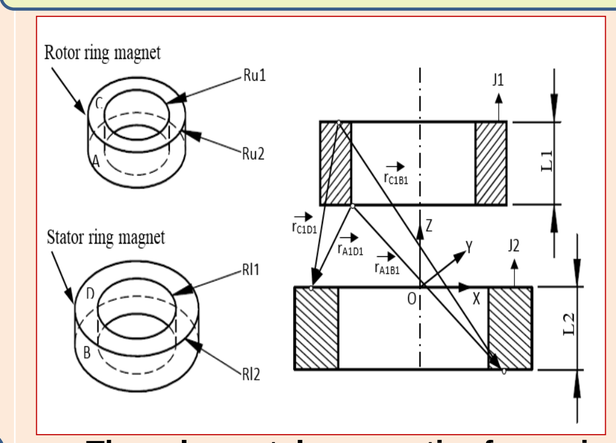
Rings Arrangement: Pair 1



Rings Arrangement: Pair 2



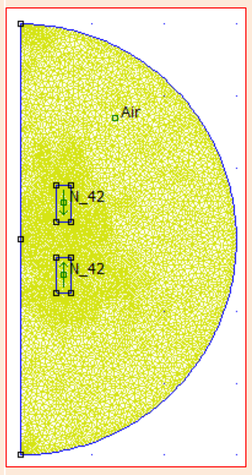
Method 1: Analytical

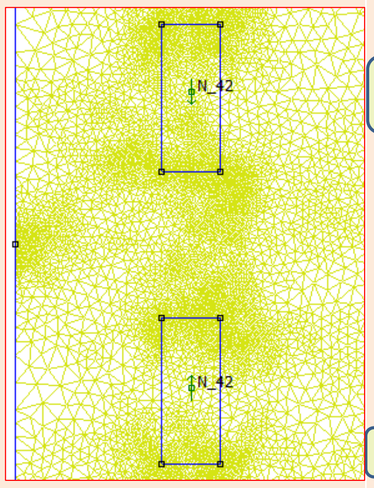


- **The elemental magnetic force is expressed in below Equation [2]. Where J and S are the magnetic polarization of the rings and surface area respectively. The elemental forces between elements of surfaces A-D, C-B, and C-D is calculated using the similar notations.**

$$\vec{F}_{A1B1} = \frac{J_1 J_2 S_{A1} S_{B1}}{4\pi\mu_0 r^3_{A1B1}} \vec{r}_{A1B1}$$

Method 2: Finite Element Software(FEMM)

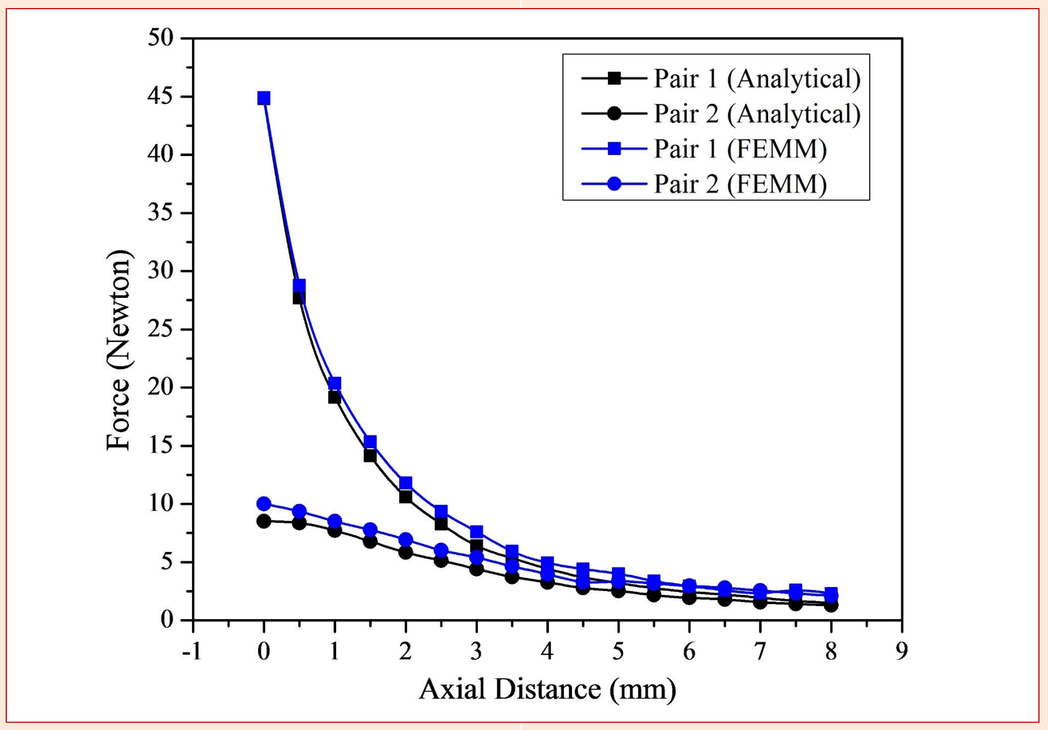




Design Data of the Ring Magnets

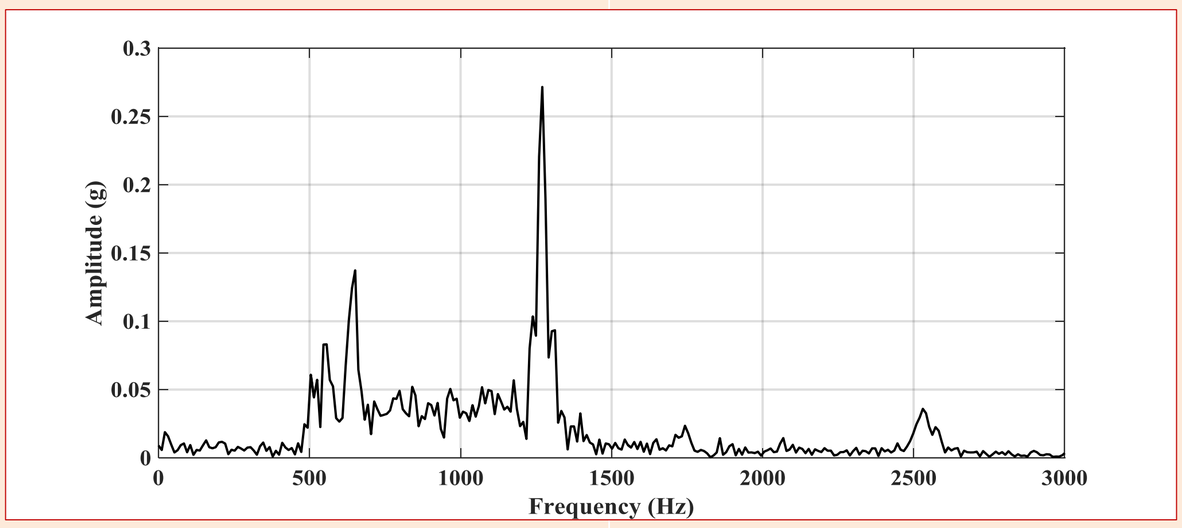
Magnetic material	NdFeB, Grade N42
J_1	1.4 Tesla
J_2	1.4 Tesla
μ_0	10^{-6} N/A^2
Pair 1 configuration	R_{u1}=5 mm, R_{u2}=7.5 mm , L_1=5 mm R_{l1}=6.35 mm, R_{l2}=9.525 mm , L_2=3.175 mm
Pair 2 configuration	R_{u1}=5 mm, R_{u2}=7.5 mm , L_1=5 mm R_{l1}=5 mm, R_{l2}= 7.5 mm , L_2=5 mm

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 axillary 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

[1]. J. P. Yonnet, “Permanent magnet bearings and couplings,” IEEE Trans. Magn., vol. 17, no. 1, pp. 1169–1173, 1981.
[2].R. Ravaud, et al., “Analytical calculation of the magnetic field created by permanent-magnet rings,” IEEE Trans. Magn., vol. 44, no. 8, pp. 1982–1989, 2008.
[3]. Bekinal, S. I., Anil, T. R. R., Jana, S., Kulkarni, S. S., Sawant, A., Patil, N., and Dhond, S.. Permanent magnet thrust bearing: theoretical and experimental results. Progress In Electromagnetics Research B, vol. 56, pp. 269-287, 2013.
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