Design and Development of Bump-type Gas Foil Journal Bearings for Cryogenic Turboexpander

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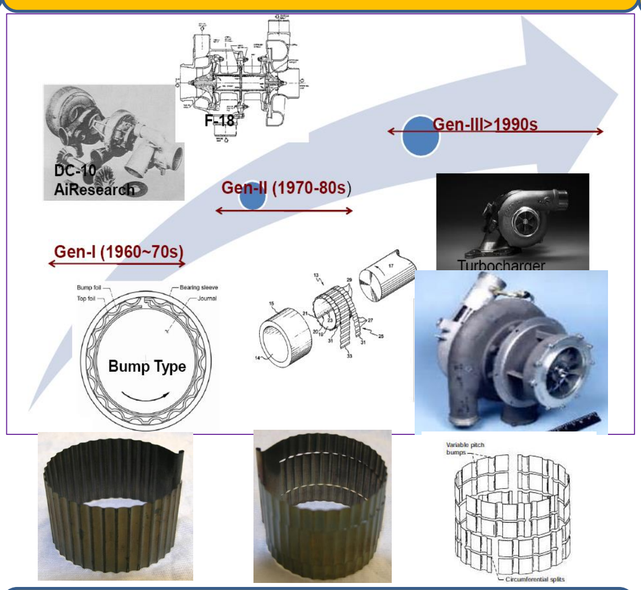
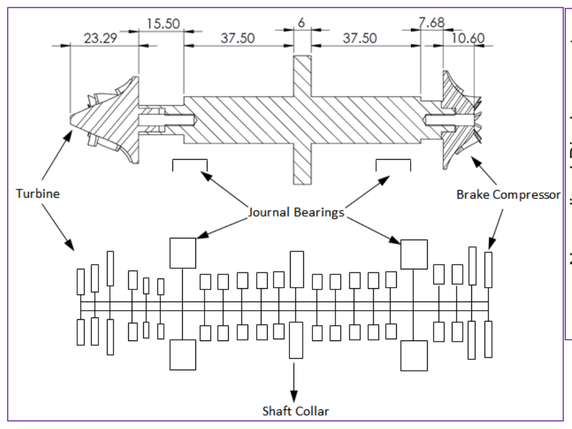
Introduction

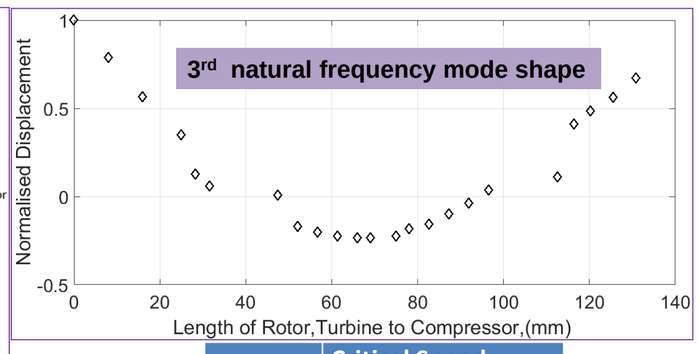
A cryogenic turboexpander is also referred as rotatory expansion device used in gas processing and cryogenic liquefaction. The operational objective of cryogenic turboexpander is to refrigerate a gas stream, by expanding the process gas in an expansion turbine. . Present work describes on design and development and performance study of bump-type gas foil journal bearing(GFJB) for a turboexpander with 16 mm rotor diameter rotating at 80,000 rpm.

History of Gas Foil Bearings



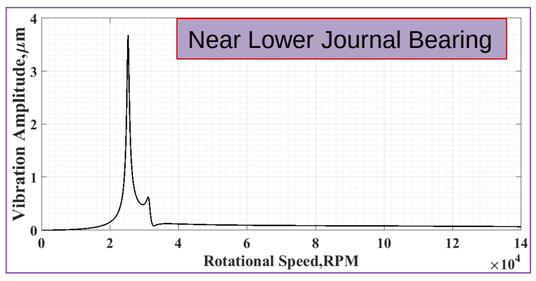
Rotordynamic Analysis using Transfer Matrix Method

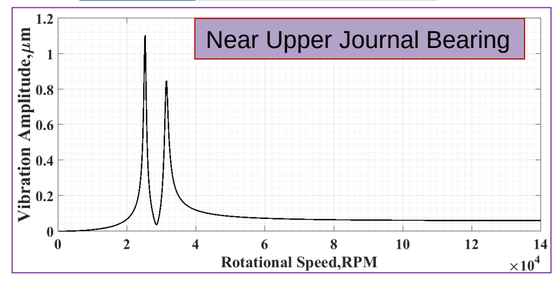


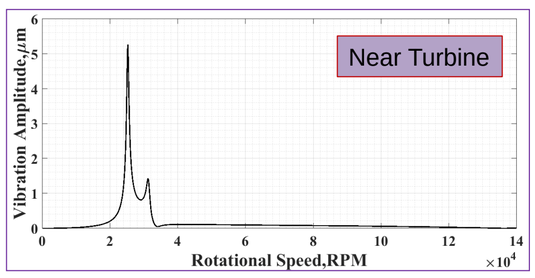


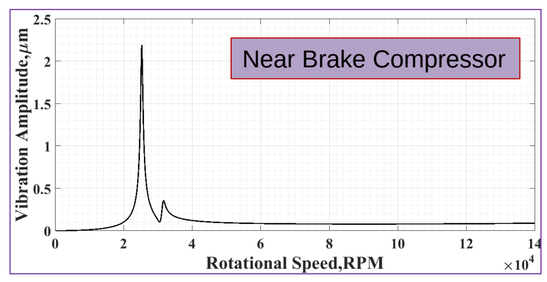
Stiffness(K_b)=8.11 E+5 N/m
Damping(Cw_b)=3.84E+5N/m/s } Perturbation Analysis

No.	Critical Speed (RPM)
1	26,752
2	29,335
3	2,09,721

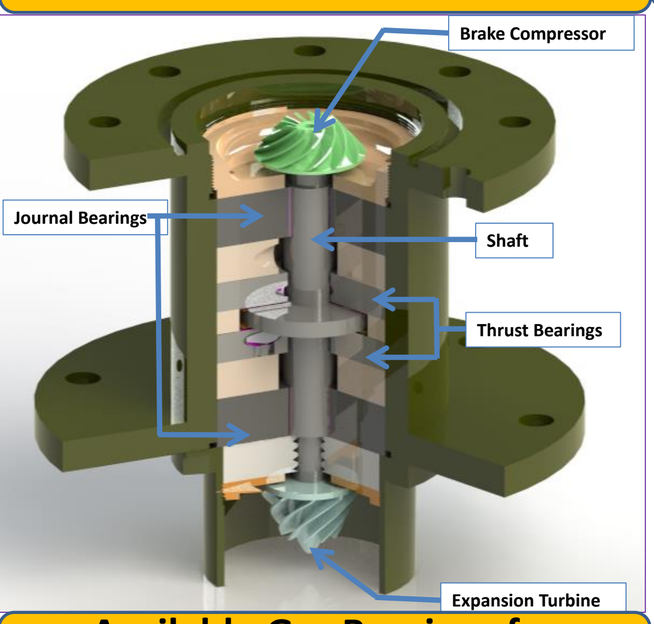




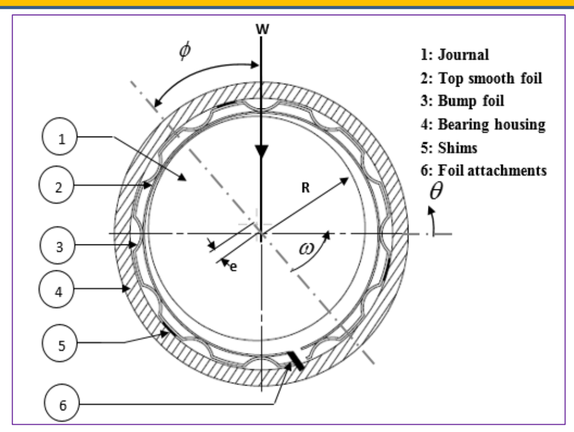




Anatomy of Turboexpander



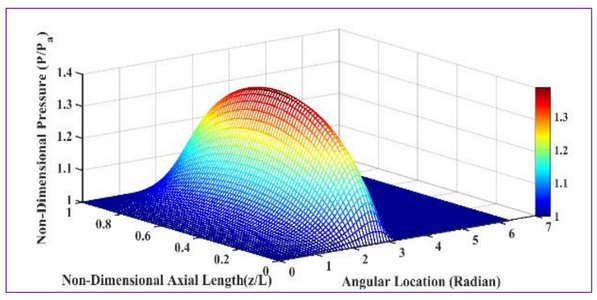
Aerodynamic Analysis of GFJB

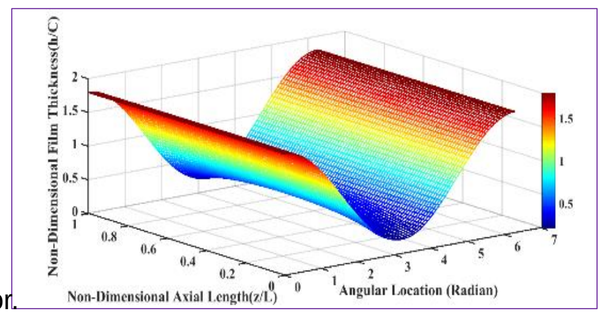


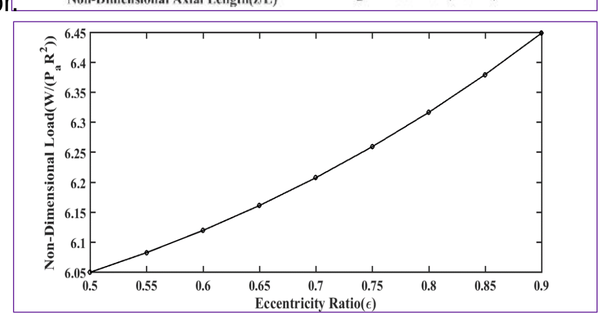
Journal bearing parameters	Dimensions
Diameter of Shaft (2R)	: 16 mm
Bearing Length (L)	: 16 mm
Rotational Speed (N)	: 80,000 rpm
Nominal Radial Clearance (C)	: 25 μm
Eccentricity ratio(ε)	: 0.8
Top Foil Thickness (tt)	: 0.1 mm
Bump Foil Thickness (tb)	: 0.1 mm
Bump Pitch (s)	: 4.2 mm
Bump Length (2lb)	: 2.64 mm
Young's Modulus (E)	: 114 GPa
Bump Foil Poisson's Ratio (ν)	: 0.36
Grid Size	: 80 × 80
Viscosity	: 178.4e-7 N.s/m2

Reynolds Equation

$$\frac{\partial}{\partial\theta}\left(\bar{p}\bar{h}^3\left(\frac{\partial\bar{p}}{\partial\theta}\right)\right)+\left(\frac{2R}{L}\right)^2\frac{\partial}{\partial\bar{z}}\left(\bar{p}\bar{h}^3\frac{\partial\bar{p}}{\partial\bar{z}}\right)=\Lambda\frac{\partial(\bar{p}\bar{h})}{\partial\theta}$$

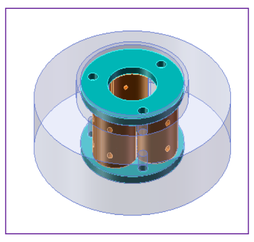




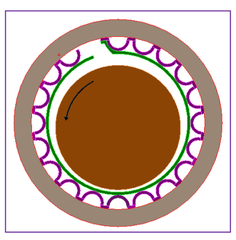


Available Gas Bearings for Turboexpander

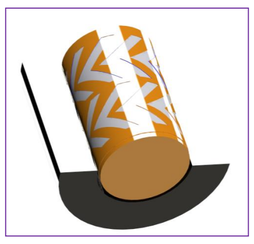
Journal Bearing:



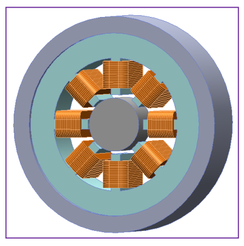
Tilting Pad



Gas Foil

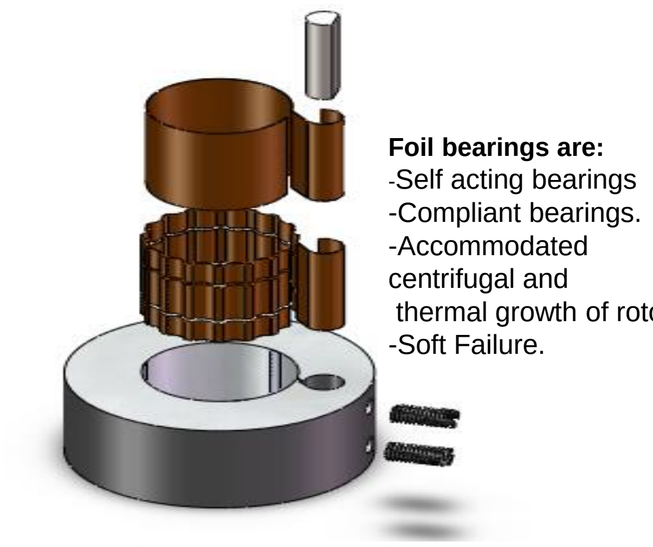


Herringbone



Active Magnetic

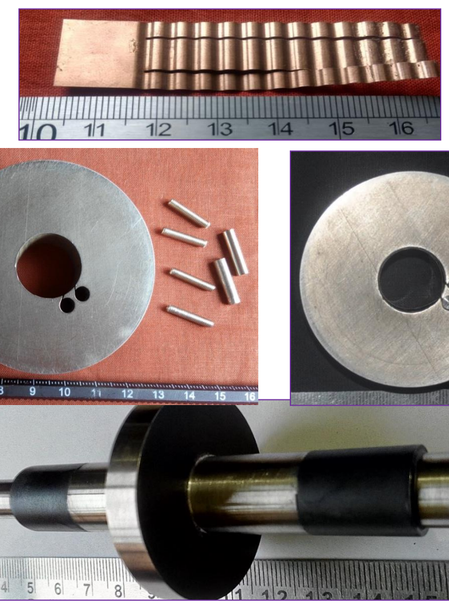
Gas Foil Bearings



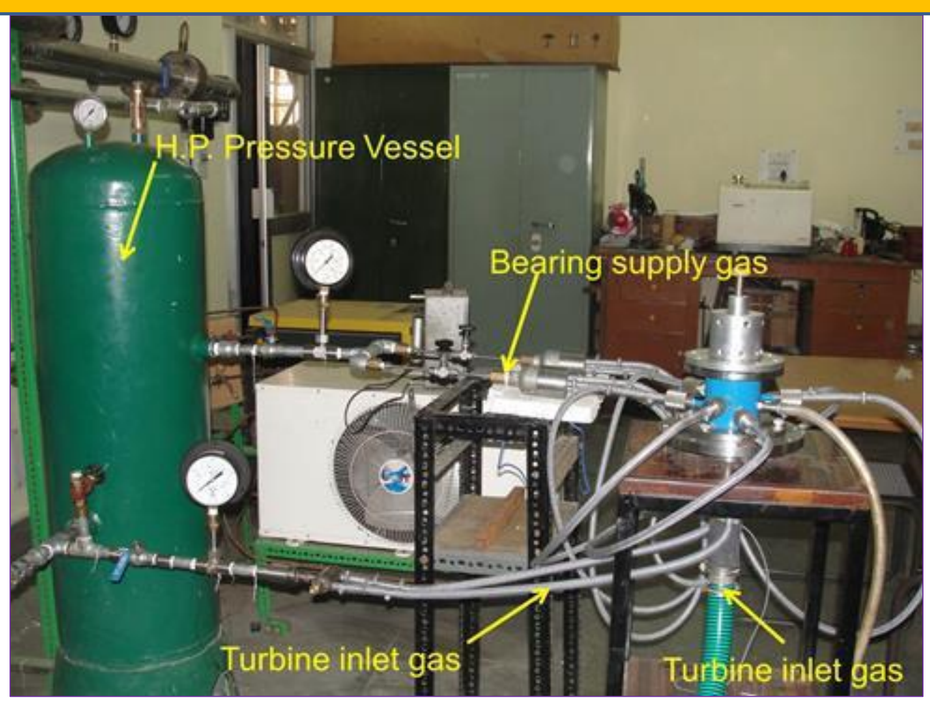
Foil bearings are:
-Self acting bearings
-Compliant bearings.
-Accommodated centrifugal and thermal growth of rotor.
-Soft Failure.

Unbalanced load for current application is 20 N.

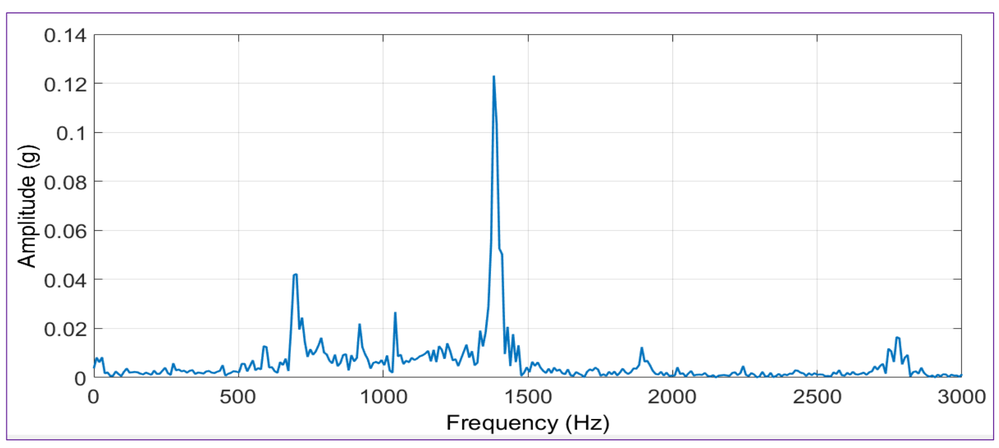
Die , punch and assembled journal bearing



Test Setup



Vibration Signature al Lower Journal Bearing



Conclusions

- From the vibration signature, the level vibration is found to be significantly reduced near both the journal bearings.
- Gas foil bearing is an alternate solution to the previously developed tilting pad journal bearings for cryogenic turboexpander.

Reference

[1] Heshmat H., Walowit J., and Pinkus O.,(1983) "*Analysis of gas-lubricated foil journal bearings,*" ASME J. Lubr. Technol, vol. 105(4), 647-655.
[2] DellaCorte C., Radil K. C., Bruckner R. J., and Howard S. A.,(2008) "*Design, fabrication, and performance of open source generation I and II compliant hydrodynamic gas foil bearings*," Tribology Transactions,51(3),254-264.
[3] Choudhury, B. K., (2013), "*Design and construction of turboexpander based nitrogen liquefier*," Ph. D. dissertation, NIT Rourkela.