A methodology for fabrication of 2nd generation gas foil thrust and journal bearing for turboexpander used in nitrogen liquefier

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Oil free turboexpander is one of the most critical parts in large no of cryogenic gas process plants, and it operates at very high speed above $2x10^6$ DN speed. Conventional liquid lubricated bearing cannot be used for such application because of short service life and issue of contamination. The alternative solution for such high-speed operation is gas bearings. Gas bearing using rigid geometry like tilting pad, spiral grooved gas bearing has been successfully developed indigenously, an attempt is made in the present research to develop a compliant surface gas foil thrust and gas foil journal bearing with excellent dynamic properties and possibilities of adaptation to changed conditions at very high speed or demanding operating conditions. This paper explains details fabrication methodology for die and punches for fabricating bump foils, bearing bases, assembly of foils and assembly of foil bearings with the rotor of the turboexpander. By providing the engineering community detailed steps of fabrication of gas foil thrust and journal bearing, the authors hope that the benefit and the true potential of this technology will be realized.

A Methodology for Fabrication of 2nd Generation Gas Foil Thrust and Journal Bearing for Turboexpander used in Nitrogen Liquefier

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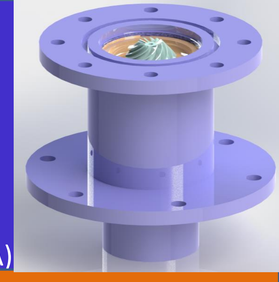
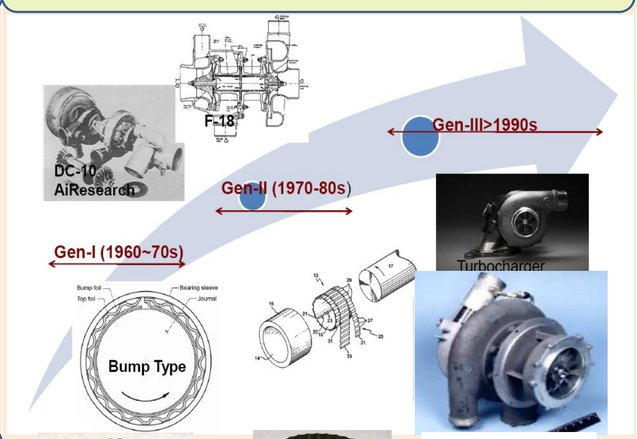


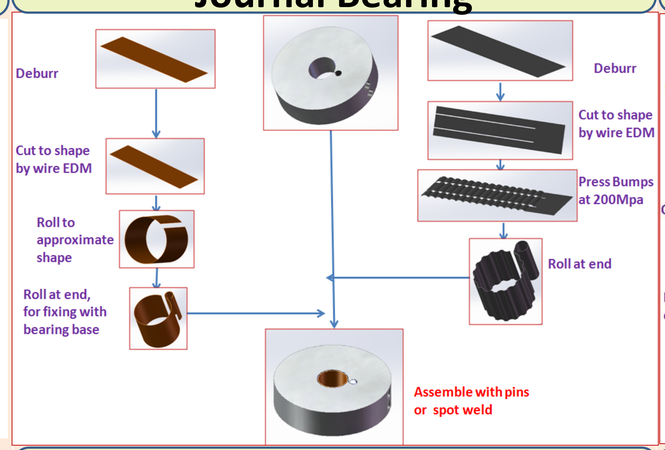
Introduction

Turboexpander is one of the most critical parts of large no of the cryogenic process plant. These turboexpanders in a typical cryogenic refrigerator run at the speed greater than 1, 00,000 RPM. Such operating conditions impose rigorous constraints on tribo-pair design and rotodynamic issues on development of turboexpander.

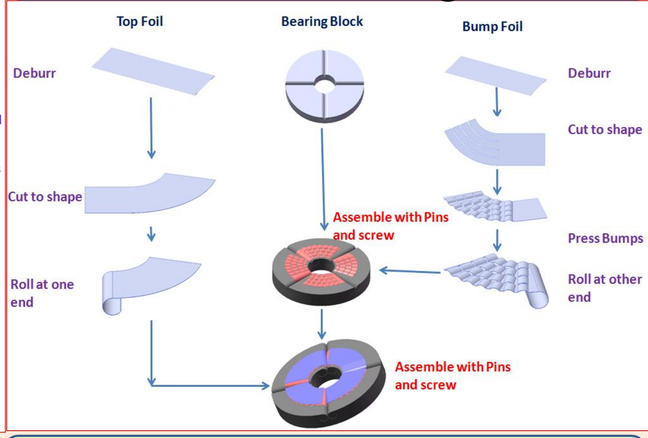
History of Gas Foil Bearings



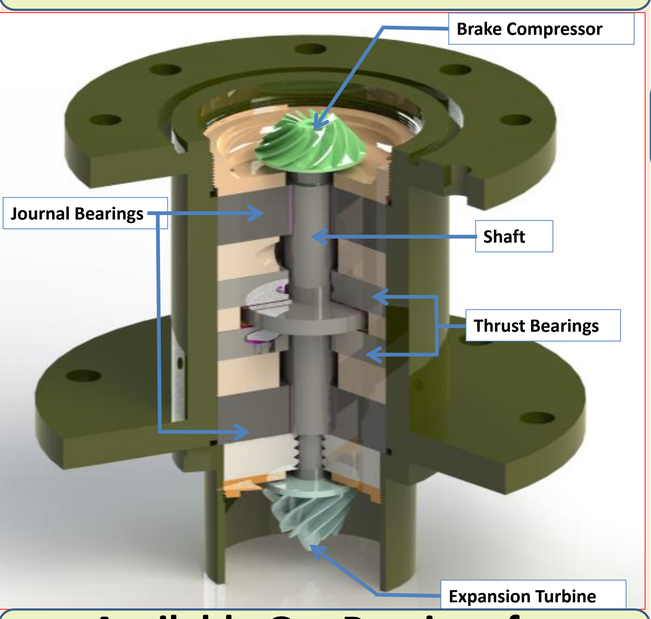
Fabrication Steps of Gas foil Journal Bearing



Fabrication Steps of Gas foil Thrust Bearing



Anatomy of Turboexpander



Steps of Design and Fabrication of Gas Foil Bearings

Step 1: Feasibility Study Specific to Application Based on Rule of Thumb.

- *Load carrying capacity*
- *Stiffness*
- *Damping*

Step 2: Aerodynamic Analysis of Bearings

- *Pressure Profile*
- *Load carrying capacity*
- *Thrust load calculation*
- *Coefficient of friction*
- *Stiffness*
- *Damping etc.*

Step3: Rotodynamic Analysis of Rotor

- *Critical Speeds*
- *Mode Shapes*
- *Unbalance Response etc.*

Step 4: Design of Die and Punch

Step 5. Fabrication of Foils

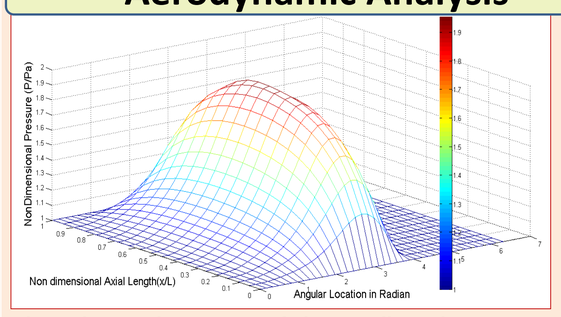
Step 6: Assembly of Foils on Bearings Base

Step 7: Coating in Rotor

Dimensions and Parameter of Journal Foil Bearings:

Bearing Radius	: 8 mm
Bearing Length	: 16 mm
Bearings Radial Clearance	: 30 micron
Top Foil Thickness	: 0.1 mm
Bump Foil Thickness	: 0.1 mm
Bump Pitch	: 4.2 mm
Bump Height	: 0.51 mm
Bump Foil Young's Modulus	:110 Gpa / 215 GPa
Bump Foil Poisson's ratio	: 0.29
Rotational Speed	: 1,40,000 RPM

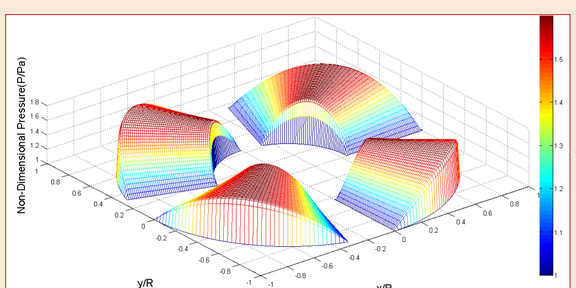
Aerodynamic Analysis



Pressure Profile over Journal Bearing surface

Dimensions and Parameter of Thrust Foil Bearings:

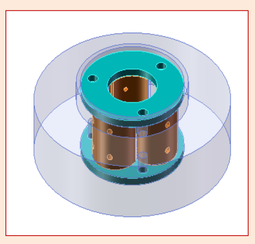
Bearing inner Radius	: 10 mm
Bearing outer Radius	: 23 mm
Top Foil thickness	:0.1 mm
Bump foil thickness	:0.1 mm
Bump height	: 0.51 mm
Bump foil Young's Modulus	: 110 Gpa / 215 GPa
Bump foil Poisson's ratio	: 0.29
Rotational Speed	: 1,40,000 RPM



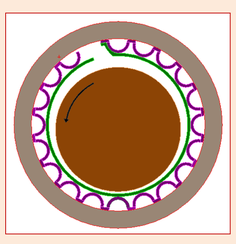
Pressure Profile over Thrust Bearing surface

Available Gas Bearings for Turboexpander

Journal Bearing:

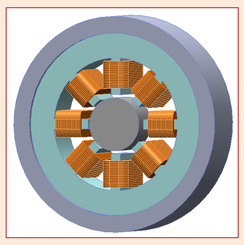


Tilting Pad



Gas Foil

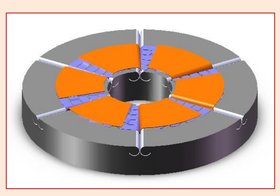
Herringbone



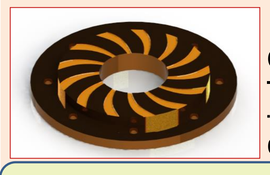
Active Magnetic

Thrust Bearing:

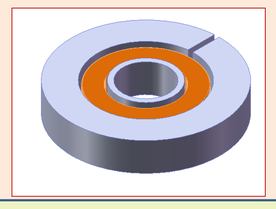
Aerostatic



Gas Foil

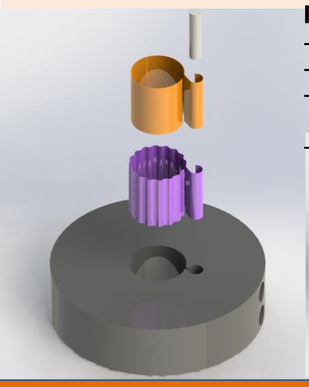


Spiral Grooved



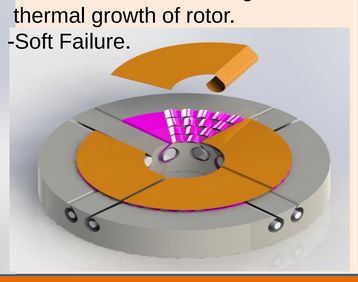
Active Magnetic

Gas Foil Bearings



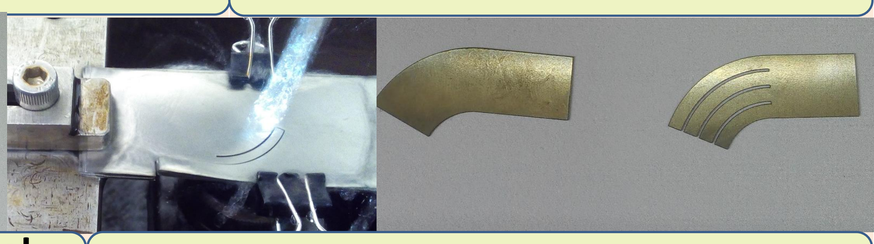
Foil bearings are:

-Self acting bearings(Aerodynamic)
-Compliant bearings.
-Accommodated centrifugal and thermal growth of rotor.
-Soft Failure.



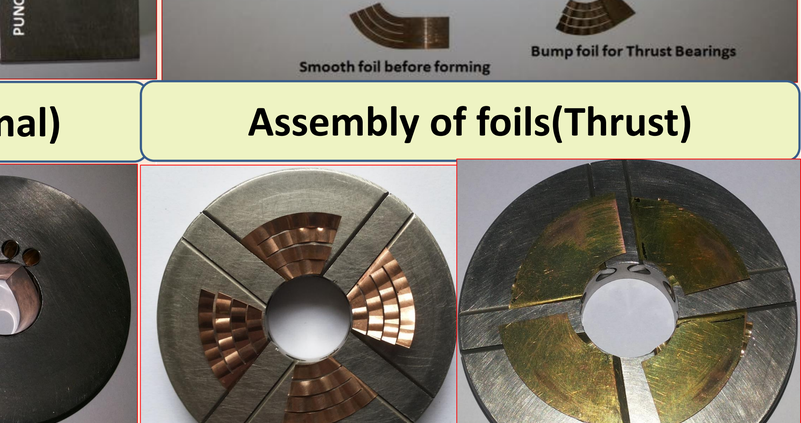
Fabrication of Foils(Journal)

Fabrication of Foils(Thrust)

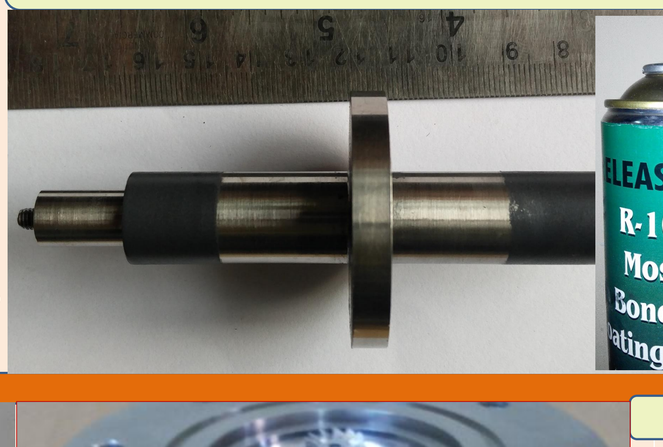


Design of Die(Journal Bump Foil)

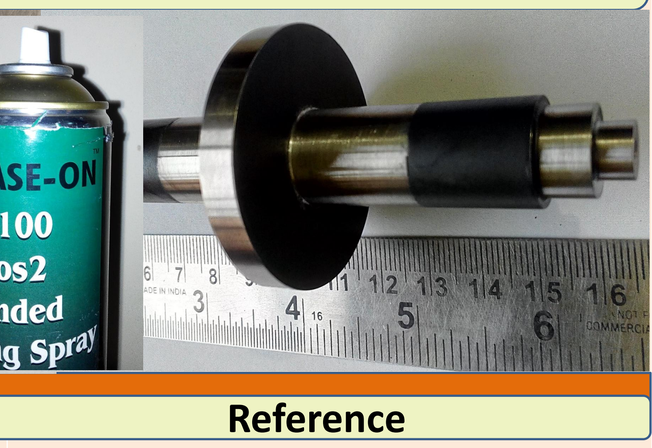
Design of Die(Thrust Bump Foil)



Die and Punch set for fabricating bump foils(Journal Bumps)

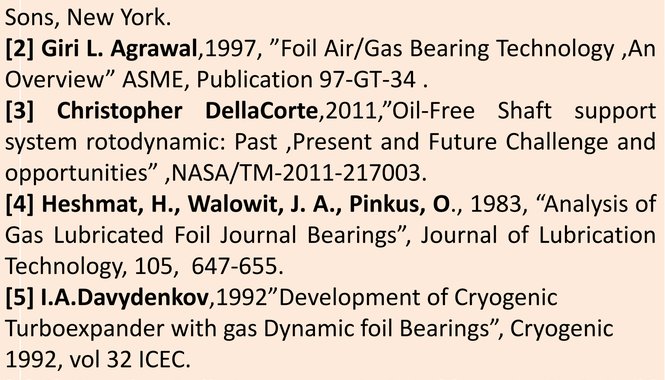


Die and Punch set for fabricating bump foils(Thrust Bumps)



Assembly of foils(Journal)

Assembly of foils(Thrust)



MoS2 Coating on Rotor

Parts of Turboexpander

Assembled Turboexpander

Reference

[1] Gross, W. A. ,1962, Gas Film Lubrication, John Wiley and Sons, New York.

[2] Giri L. Agrawal,1997, "Foil Air/Gas Bearing Technology ,An Overview" ASME, Publication 97-GT-34 .

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[4] Heshmat, H., Walowit, J. A., Pinkus, O., 1983, "Analysis of Gas Lubricated Foil Journal Bearings", Journal of Lubrication Technology, 105, 647-655.

[5] I.A.Davydenkov,1992"Development of Cryogenic Turboexpander with gas Dynamic foil Bearings", Cryogenic 1992, vol 32 ICEC.

[6] **Christopher DellaCorte,Antonio R. Zaldana, Kevin C. Radil** ,2003"A Systems Approach to the Solid Lubrication of Foil Air Bearings for Oil-Free Turbomachinery", ASME J of Tribol., 126,