

# MiTi<sup>®</sup> Developments

Mohawk Innovative  
Technology, Inc.



Vol. 19

September 2004

## FOIL GAS BEARINGS ENABLE OIL-FREE COMPRESSOR BREAKTHROUGH

Mohawk Innovative Technology, Inc. (MiTi<sup>®</sup>) has enabled the breakthrough development of a truly oil-free plant air compressor. Working with Samsung Techwin Co., Ltd. of Korea, MiTi applied its proprietary compliant foil gas bearing design to support a 25 lb. rotor with integral permanent magnet motor on two radial bearings. A double acting thrust bearing controls both axial thrust and the tip clearance of an impeller overhung on each end.

Figure 1 shows an isometric view of the *Turbo-Master*<sup>®</sup> Micro TM Series compressor line, which features units rated at 125, 150, or 175 hp. Totally enclosed and with a control panel on one end, this compact design has a nominal weight of 2,500 Kg, a footprint (mm) of 2,100L x 1,440W, and is 1,816 mm high. Resulting floor space requirements are the smallest in the industry and no special support foundation is required.



Figure 1. 150 hp Turbo-Master<sup>®</sup> Oil-Free Compressor

Environmentally friendly features are the elimination of the lube oil system, oil waste disposal, oil filter changeouts, oil condensate considerations, and gear or pump noise. Sound level measurement outside the enclosure is 65dB(A).

The ultra-high (70 krpm) operating speed, with 10% over-speed margin, is enabled through use of MiTi foil bearings. Superior aero efficiency over a wide operating range is attained through use of a matched pair of advanced impeller designs with backward-leaning blades, each discharging to double-row, vaned diffusers to attain up to 10 bar A.

The package has only one rotating part (rotor-motor-impeller assembly). The two wear resistant stainless steel impellers and long-life foil bearings, plus the special engineering effort expended to minimize the number of component parts with a finite life, assures low maintenance costs and extended maintenance intervals.

Elimination of the entire oil system, including reservoir, pumps, filters, and piping avoids the major need for

frequent maintenance intervals and contributes to high reliability. Figure 2 offers comparisons of Oil-Free Screw and Micro TM compressor maintenance and operating costs, plus space requirements.

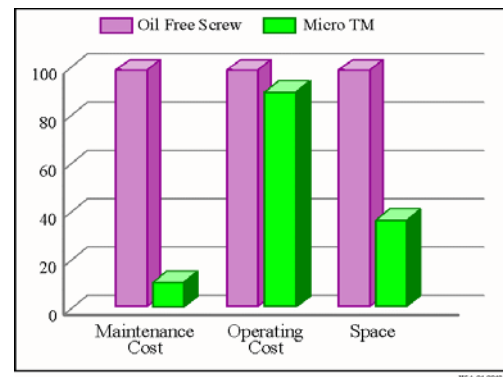


Figure 2. Operating Cost and Space Comparisons

The MiTi compliant foil gas bearing design combines hydrodynamic and mechanical actions of the bearing components to surpass the stiffness and damping properties of oil film bearings. Operation over Critical (bend) Speeds has not been achieved via any other foil bearings to date. Supported by a bearing cartridge, the compliant element has a corrugated shape that enables the designer to incorporate a desired mechanical stiffness value through metal gauge selection. The number and span of each corrugation can be designed to meet or exceed oil film dampers. The flexing of each corrugation, when under dynamic loading, causes minute sliding of the contact points along the cartridge surface. The combined static and dynamic friction values of all corrugation contact points provide the major portion of the mechanical damping action.

These two actions compliment the stiffness and damping values of the hydrodynamic actions of the air film that levitates the rotor. The combined values of these two functions in essence duplicate the stiffness and damping normally provided by an oil film bearing. Figure 3 illustrates the key MiTi foil bearing design features.

The smooth top foil rides on top of the corrugations and provides the surface needed for the generation of a hydrodynamic air wedge to levitate the rotor. Levitation by the air film wedge eliminates wear inducing contact with the bearing. Long-life MiTi systems routinely achieve 100,000 start/stops without damaging wear. Friction

between the contact points of the compliant element corrugations and the smooth top foil provides a portion of the total corrugation mechanical damping value.

The persistent development work supported by many U. S. government contracts and pioneered by MiTi engineers over more than 20 years, has resulted in powerful, validity proven analytical procedures that are used to optimize the design of these rotor-bearing systems for each application.

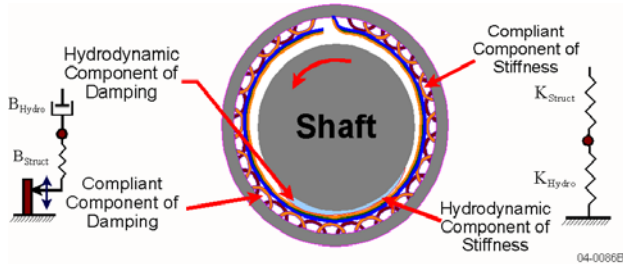


Figure 3. Compliant Foil Bearing Components

MiTi has three proprietary coatings (KOROLON™) for up to 1500F applications, each with coefficients of friction a fraction of that of Teflon. They are resistant to alkalis and solvents and have extremely durable surfaces that also have healing properties for foreign debris induced penetrations.

KOROLON coatings have elasticity and highly developed proprietary adhesion technologies that provide dramatically improved abrasion resistance to metal surfaces. Spray gun process parameters are controlled to optimize the properties critical for high temperature applications. Crystallographic types and sizes are varied for specific physical applications. These coatings are also being applied to MiTi foil bearings for turbochargers and gas turbine engine applications.

These unique and outstanding KOROLON properties support very long foil life due to their ability to enable rapid lift-off in addition to having superior wear characteristics. Low friction drag allows for significant reductions in starting device sizing and system costs. The low friction and levitating air film also permit rapid acceleration of the rotor.

The significant viscosity difference between oil and gas enables substantial efficiency gains to be realized through use of a gas bearing. Analytical means for initial sizing and placement of foil bearings have been highly developed. Thermal management of the bearing systems is effectively integrated with the cooling for the integral drive electric motor mounted between the bearings.

The designer is able to utilize more than one layer of the compliant (corrugated) element to achieve a wide range of damping and stiffness values. The additional layer provides separate properties (i.e., increasing stiffness as deformation progresses). The use of simulators enables the optimization of specific design features of commercial grade foil bearings, providing outstanding performance and reliability.

MiTi foil bearing load capacities (defined as applied load W/projected bearing area LxD) have been increasing at a rapid rate due to vigorous developmental testing. In the past three years, MiTi thrust bearing capacities have been increased from 30 psi to over 85 psi. Radial bearings have ratings up to 100 psi. Applications can be horizontal or

vertical. MiTi bearings have passed rigorous mobile T/C testing programs. Bearing chamber temperatures can be held at very high values, reducing challenges in system design thermal managements.

Past rotor weight limitation to 100 lb. to minimize startup wear was challenged by MiTi engineers. An innovative, proprietary bearing system that utilizes unique performance characteristics of the MiTi Foil Bearing design has been developed to permit levitating heavy rotors on foil bearings. Each case must be individually analyzed, but MiTi foil bearings are now possible for application to a wide range of turbo machinery. We welcome your inquiries and offer free initial assessments of proposed applications. If they are not yet applicable, we will tell you so and why.

### **Key Features of MiTi® Gen III Foil Bearings**

Extraordinary Load Carrying Capacity

- Radial, 100 psi; thrust, 85 psi

No Speed Limitation

- Demonstrated speeds up to 700,000 rpm

Can Replace & Exceed Performance of all Known Bearings

- Extreme temperatures up to 1500F
- Fulfills needs where no other bearing can do

Exceptional Start/Stop Characteristics

- Low friction enhances rapid lift-off, low wear
- Low drag minimizes starting power needs

Drastic Reduction in Power Losses/Heat Generation

- Low viscosity of gas reduces drag

KOROLON Coatings Eradicate Metal-to-Metal Contact

- Low friction coating controls start/stop wear
- Wear resistance properties greatly extend bearing life
- Over 100,000 start/stop life demonstrated
- Exceeds air cycle machine life requirements by 300%
- Electric resistance capability is 3+GΩ/mm
- Extraordinary thermal expansion and over 50% elongation without failure, high thermal barrier
- Self-healing property mitigates foreign element contamination/debris infusion

Unlimited Bearing Size Scalability Demonstrated

Completely self-acting hydrodynamic action

- Requires no external pressurization

Capable of Providing Aircraft Quality Tip Clearances

- Increased compressor/turbine efficiencies

Self-Alignment Adjustment Features for Rotating Group

- For static, magnetic & dynamic misalignments

Unparalleled Price to Performance Ratio

- Huge savings shown by life cycle evaluations

High Shock & Vibration Survivability

- Vehicular & mobile system maneuver tolerance

Operation Orientation

- Can operate in any orientation, including vertical

Bearing Material Flexibility

- Material can be altered to suit the application

For additional Information, contact:  
 Mohawk Innovative Technology, Inc.  
 1037 Watervliet-Shaker Road  
 Albany, New York 12205  
 Telephone: (518) 862-4290 □ FAX: (518)862-4291  
 E-mail: [Marketing@miti.com](mailto:Marketing@miti.com) Website: <http://www.miti.com>