

---

# MiTi Developments

Mohawk Innovative  
Technology, Inc.



Vol. 22

February 2005

---

## High Performance Foil Thrust Bearing Test Rig Developed

Mohawk Innovative Technology Incorporated (MiTi<sup>®</sup>) has developed an advanced, state-of-the-art, high-speed, high-temperature and totally oil-free thrust bearing test rig (see Figure 1). This innovative test rig offers a revolutionary, oil-free platform to advance the development of hydrodynamic, compliant foil thrust bearing technologies over a broad range of applications. This rig is capable of operating at speeds to 80,000 rpm, temperatures to 1200°F and with axial loads approaching 400 pounds. In addition to the developmental testing of high-temperature compliant foil thrust bearing designs, this test rig is well suited and could be easily adapted for testing dynamic seals, cryogenic bearings and seals and a large variety of dynamic turbomachinery components and materials, including advanced, high temperature, solid film lubricant coatings, such as MiTi<sup>®</sup>'s Korolon™ series.

In effect, with the development of this test rig MiTi<sup>®</sup> has created a horizontal tribometer with a wide range of possible applications. With this completely oil-free test rig, MiTi<sup>®</sup> is able to continue advancing state-of-the-art in compliant foil thrust bearings and verify new bearing technologies, enabling rotors to operate at higher speeds, thrust loads and temperatures than ever before attained.



Figure 1. High temperature foil thrust rig.

### Motivation and Rig Overview

With the relentless demand for machines capable of operating at ever greater speeds, power densities and temperatures, it is essential that bearing technology, a crucial foundational element, keeps pace. MiTi<sup>®</sup>'s existing compliant foil journal bearings are capable of

operating at speeds in excess of 700,000 rpm (or over 6 Million DN, where D is bearing diameter in mm and N is speed in RPM). While journal bearings have been advanced significantly in the past decade, very little theoretical or experimental development work has been conducted on foil thrust bearings since the mid 1980's. As a result, MiTi<sup>®</sup> determined that in order to meet the increasing performance demands being placed on these bearings, to match the advances in journal foil bearings and to expand the application potential of foil bearings, that a radically innovative test facility dedicated to foil thrust bearing research and development must be created.

Under a NASA sponsored SBIR program, MiTi<sup>®</sup> established specifications for the needed test platform. Based on criteria for earlier development test rigs that MiTi<sup>®</sup> engineers had built and used, it was determined that the test rig must be completely oil-free, using foil journal bearings and an electromagnetically controlled thrust loader bearing. Journal bearings are essential to the test rig, enabling tests of the thrust foil bearing at temperatures to 1200°F without the need for sophisticated heat dams and water cooling jackets, as would be required for rolling element bearings. Additionally, at the anticipated thrust loads and speeds, conventional bearings would be impractical since the expected 3.0 Million DN value would exceed even hybrid ceramic bearing capabilities.

Advanced foil thrust bearing requirements dictated that the rig must be capable of operating at speeds up to 80,000 rpm with thrust loads to 400 pounds and able to accommodate a variety of different thrust bearing designs and sizes. Other key criteria for this test rig were operation at elevated temperatures on the order of 1200 °F and the ability to study and test the effects of angular misalignment on the load capacity of foil thrust bearings.

These primary design goals have been achieved with great success. By combining a pair of proven MiTi<sup>®</sup> foil journal bearings with an active magnetic thrust bearing, the test rotor is supported by a stable, robust and completely oil-free system. The rotor has been operated at speeds exceeding 80,000 rpm with loads on a development thrust bearing under test as high as 300 pounds. Under these conditions, runner tip speeds in excess of 1800 ft/sec have been achieved.

A simple schematic of the test rig is given in Figure 2 and a photo of an advanced, high capacity MiTi® thrust foil bearing in Figure 3. The rig consists of a 12-inch long rotor that is driven by a 10 horsepower air turbine. The rotor is supported on two MiTi® foil journal bearings and a magnetic thrust bearing that can support static loads over 400 pounds and dynamic loads to 300 pounds. The test thrust bearing is mounted on a hydrostatically levitated piston so that frictionless axial and rotational motions are possible. Loads can be generated on the test bearing by pressurizing the end of the loader piston housing opposite to the test bearing. The hydrostatic support used for the loader piston eliminates parasitic torque loads on measurements of test foil thrust bearing torque. Elevated test chamber temperatures can be obtained by using the electric band heater, by injecting heated air into the thrust bearing cavity or a combination of both. Air cooling is used to limit heating of the magnetic bearing and assist in controlling the temperature of the journal bearings. A computerized system allows for thorough monitoring and control of the system. Magnetic thrust bearing control is accomplished with a PC based DSP controller and custom software, while data acquisition of speed, imposed load, bearing reaction torque, bearing temperatures and cooling air flow and temperature data are acquired using a LabView system.

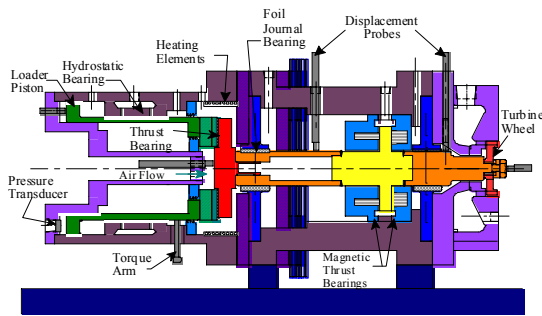


Figure 2. Schematic of foil thrust bearing tribometer.



Figure 3. Advanced high load thrust foil bearing.

## Results and Conclusions

To date, more than 750 tests have been run with the thrust bearing test rig from speeds below 10,000 rpm to as high as 80,000 rpm with imposed axial loads exceeding 300 pounds. Throughout testing, the MiTi® designed magnetic thrust bearing and MiTi® foil journal bearings

have proven to be capable of accommodating planned thrust bearing overload limit parameter charting tests at speeds as high as 80,000 rpm. This robustness has provided MiTi® test engineers with the confidence needed to extend the borders of this new technology without having undue concern for the integrity and durability of the test facility. The results of bearing specific power loss and load capacity testing are presented in Figure 4 and Figure 5 respectively, showing that a substantial increase in foil bearing load capacity has been achieved.

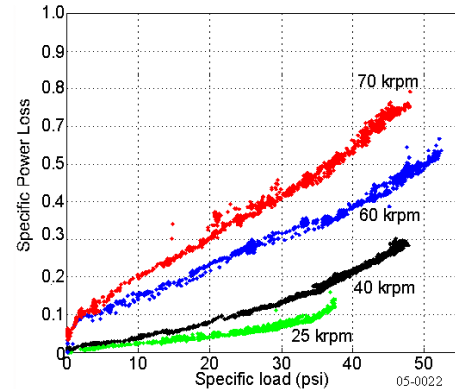


Figure 4. Power loss vs. Load and Speed

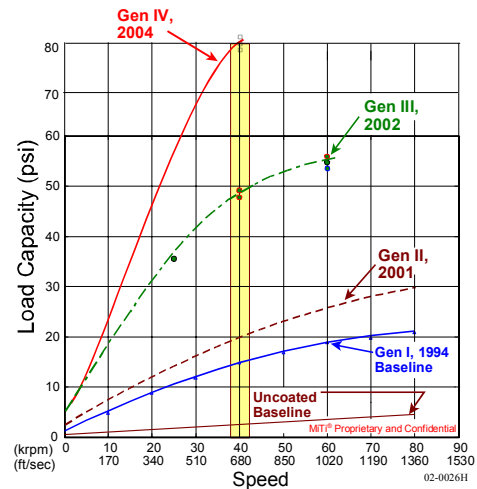


Figure 5. Advances in MiTi® Gen IV thrust foil bearing load capacity show a 400% improvement over Gen II.

This test rig has made it possible for MiTi® to develop an oil-free foil thrust bearing with performance and capabilities unmatched by any other foil bearing available today. MiTi®'s latest thrust bearings exceed the capabilities of industry standard Gen II thrust bearings by 400%. With test facilities such as these, MiTi® is in a commanding position to meet the increasing performance demands of the rapidly evolving turbomachinery industry.

Mohawk Innovative Technology, Inc.  
 1037 Watervliet-Shaker Road  
 Albany, New York 12205-2033, USA  
 Tel: +1 518-862-4290 Fax: +1 518-862-4293  
 Email: [program\\_dev@miti.cc](mailto:program_dev@miti.cc)  
 Or visit our web page at: [www.miti.cc](http://www.miti.cc)  
 © 2005 Mohawk Innovative Technology, Inc. all rights reserved