MiTi Developments

Mohawk Innovative Technology, Inc.

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Tribometer for High Performance Tribomaterials

Mohawk Innovative Technology, Inc. (MiTi®) has developed a high speed, high temperature tribometer for enhancing the characterization of advanced solid lubricant materials. This unit, the HTP5, provides a faster, reduced *cost means for conducting reliable correlative testing to support continuing bearing performance advances. This friction and wear test system (pin-on-disk type tribometer) offers durable, elegant features , with minimum complexity, yet superb performance. High speed (5000 rpm) and high temperature (900^oC) capability, accompanied by extremely high accuracy, a purge chamber, a cooling system, and the ability to accommodate various size specimens are key features. Extremely low disk run-out has been achieved to minimize variation in the actual applied load due to dynamically induced errors. Reduction of dynamic and overall system-induced errors in conducting tests enables the gathering of more accurate tribological phenomena. This permits precise elucidation and interpretation of data, supporting more efficient development of ever higher performance tribological components.*

Features and Benefits Offered by the MiTi® HTP5

FEATURES	BENEFITS
Reliable Correlative Tests	Reduced Cost and Time Superior Results
Simple, Elegant Features	Ease of Use Procedural Accuracy
High Speed & Temperature	Wider Testing Range
Reduced Dynamic, System Induced Errors	Valid Tribological Phenomena

Introduction

A notorious, uncharacterized relationship exists between the coefficient of friction, wear, and sliding velocity as a function of the global dynamic properties of a tribotester (i.e., manufacturing accuracy of tribocomponents, mass, unbalance, stiffness, frequency, etc.). Resulting friction and wear coefficient values obtained from tribometers contain a certain degree of error in complex form, and the data obtained should be interpreted with careful calculations and measurements in order to account for error inducing dynamic forces. These effects are compounded when dry contact tribomaterials are the subject of the investigation. Thus, the design of tribological testers for evaluating the performance of materials under the extreme conditions that advanced systems must withstand is a challenging risk. It must be approached in a systematic manner by a tribologist who understands not only the tribomaterial properties and the ultimate application of the materials being studied, but also the dynamics of the tribometer itself. MiTi®'s vast experience and knowledge of these conditions were fully utilized during the design of the HTP5.

General Description of the HTP5 Tribometer

The MiTi® HTP5 is a pin-on-disk type Tribometer, designed to support accurate friction and wear characterization of advanced materials, coatings, and lubricants under simulated severe operating conditions, with careful attention given to dynamic factors. Conventional tribotesters are primarily useful for initial candidate material screening, but offer limited operating simulation of systems. Side and top views of the HTP5 are shown in Figures 1&2.

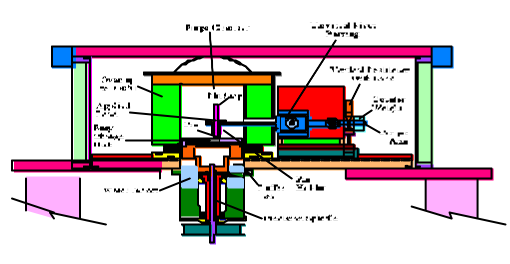

Figure 1. Side View of HTP5 Tribometer

Figure 1 shows critical elements of the HTP5, including the spindle, pin holder assembly, and the oven. A purge chamber and double labyrinth seal arrangement is included in the facility to minimize the volume of gas required during testing. Insulation surrounds the oven chamber as well as the bottom of the static platform to protect the drive system from the elevated temperatures, in addition to minimizing structural distortions that may affect alignment during testing. Heating elements are completely enclosed in the oven shell to prevent test sample contamination by insulation or other particles.

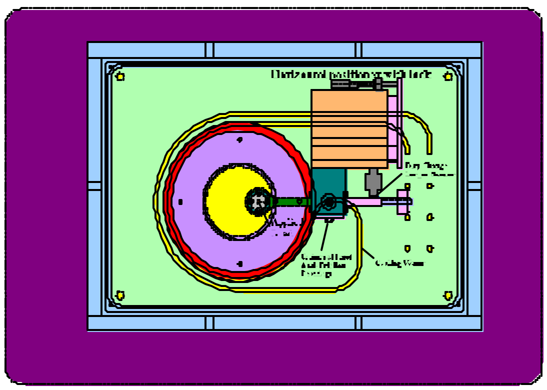

Figure 2 Top View of Tribometer

Figure 2 shows that as the disk is rotated, friction between it and the pin induces a rotation of the torque arm that is measured via a load cell. To permit multiple tracks per test disk, a horizontal micropositioner is utilized to move the entire torque arm assembly towards and away from the center of test disk rotation. It incorporates a lock to secure the slide and prevent vibrations/structural noise from affecting the data and provides a means to change the diameter of the wear tracks from 6.35 to 63.5 mm (0.25 to 2.5 inches). A vertical microprocessor raises and lowers the load arm.

Not shown in Figure 2 are the thermocouples used in monitoring chamber, inlet purge gas, table, and bearing for control and operational safety purposes and other temperatures for test data.

This system is capable of speeds up to 5000 rpm (70,000 rpm with an air turbine drive), environment temperatures to 900°C (1652°F), continuous analog output, and automatic cutoffs. Additional capabilities of the HTP5 include normal loading from 100 to 500 grams (0.22 to 1.1 lb.), multi-track testing on the same disk specimen, a controlled environment via purge gas chamber, the ability to accept specimens ranging from 3.18 to 79.4 mm (0.1225 to 3.125 inches) in diameter, with thickness ranging up to 6.35 mm (0.25 inch) thick, and the ability to accept pin specimens of 1.59 to 6.35 mm (0.0625 and 0.25 inch) diameter.

In many pin-on-disk tribotesters the test specimen disk is placed on a flat surface, which makes the bottom of the disk the reference surface. In this arrangement, any non-parallelism between the top and bottom surfaces of the disk will introduce a dynamic error in the pin force that is normally ignored. The HTP5 spring mounts the test sample disk inside a cap that has a precision lip at the top of the bore. The test sample disk is spring loaded up against this lip, which locates it by its outer top surface. This simple reference point procedure eliminates the non-parallelism problem while reducing specimen complexity and manufacturing cost and simultaneously greatly improving accuracy of the results.

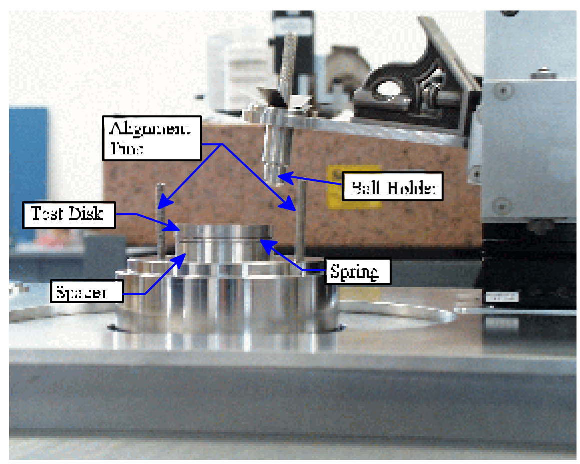

Figure 3. Test Specimen Area with the Enclosure Removed

The disk and holder shown in Figure 3 are supported on a precision spindle driven by a variable speed motor. Speeds of up to 5000 rpm realistically simulate conditions that are encountered above the conventional 3600 rpm tribometer speed. The design permits substitution of an air turbine spindle capable of up to 70,000 rpm with minimal changes.

The pin is held within an assembly that allows the pin to be locked in place so that it does not rotate within the holder. Similarly, the test sample disk is constrained from rotation by the pressure of the spring holding it up against the lip of the cap. The pin assembly can be easily removed from the torque arm in order to examine the pin surface wear at specified test intervals and then returned to the same position for continued testing. The torque arm is supported by a low friction universal pivot bearing and balanced via a counterweight and precision level.

Particular attention has been paid to the design of the pin/torque arm, that utilizes a lightweight, dynamically and statically balanced torque arm with integral level indicator to minimize dynamic load fluctuations. A pin holder cup approach allows easy change outs of individual pin specimens. These are less expensive than fully assembled units and may be used for multiple tests without refinishing. Applying the load directly over the pin eliminates the calibration step.

In cases where potential environmental contamination of the chamber by the weights is a problem an external loading location is provided on the torque arm. The torque arm dead weight is optimally minimized and balanced with a counterweight. Antifriction universal bearings are used in the torque axis to minimize the parasitic friction and drag that would otherwise influence the test measurements. Finally, a non-contacting magnetic flux displacement sensor is used to measure wear rate, to provide a measure of initial alignment, and to measure system health via a detection of any fluctuations in the vertical position of the torque arm.

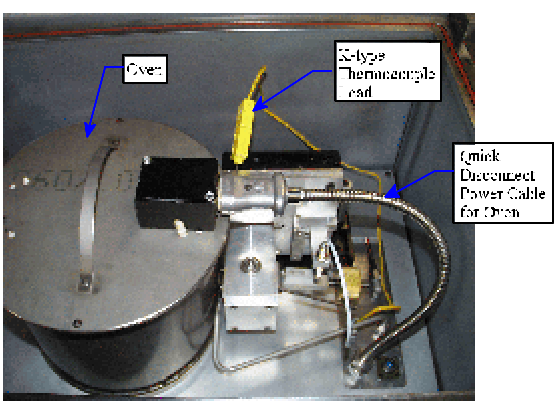

Figure 4. High Temperature Oven Enclosure

Figure 4 shows the test specimen area with the high temperature oven enclosure in place. A cooling water jacket and cooling buffer gas protect the spindle, its components, and the high temperature grease-packed ball bearings from the high oven chamber (900°C) temperatures. The oven chamber and secondary chamber are purged of contamination gasses by a purge gas, such as argon or nitrogen.

System Accuracy

Through proper attention taken to critical system alignments and dynamics, the HTP5 Tribometer has a measured maximum run out at 5000 rpm of less than 0.0001 inches. This results in a total error due to system dynamics over the total range of load and speed of less than $^{+}$/- 2.6 %. This achievement, combined with MiTi®'s method of analytically eliminating residual dynamic error, assures the most reliable interpretation of accurate data.

Key Features of the HTP5 Tribometer

- Speeds up to 5000 rpm, with an option to operate up to 70,000 rpm
- Temperatures up to 900°C
- Massive frame to minimize sensitivity to external vibrations
- Complex errors due to system dynamics

vastly minimized

- Remaining errors accounted for by precise analytical methods
- Unique mounting method relaxes strict specimen tolerances

The MiTi® stand-alone facility includes engineering design offices, research and development testing laboratories, and manufacturing facilities to support the production of compliant foil gas bearings and seals, magnetic bearings, and auxiliary bearings.

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