Proceedings of Malaysian International Tribology Conference 2015, pp. 111-112, November 2015

Effect of humidity on limiting friction: An experimental investigation

K. S. Pondicherry[1]*, F. Wolf[2], G. Krenn[1]

[1)] Anton Paar GmbH, Anton-Paar Strasse 20, 8054 Graz, Austria.
[2)] Anton Paar Germany, Hellmuth-Hirth Strasse 6, 73760 Ostfildern, Germany.

*Corresponding e-mail: kartik.pondicherry@anton-paar.com

Keywords: Static-friction; Humidity; MCR-Tribometer

ABSTRACT – The current study elaborates on a novel test methodology developed for investigating the effect of humidity on static−friction behavior of tribological contacts at laboratory scale. The break-away (limiting) friction, of two different steel–polymer tribopairs was investigated as a function of humidity on a modular tribometer with a ball-on-three-plates configuration at room temperature. Results showed that the effect of humidity strongly depends upon the hygroscopic properties of the test surface.

1. INTRODUCTION

Surface characteristics such as roughness, visco-elastic properties, chemical activity, adsorbed layers, etc. strongly influence the tribological behavior of materials [1-3]. In the current report, we present a novel methodology which aids in determining the influence of humidity on the break-away friction of tribological systems at model scale with high precision.

Humidity is the amount of water vapor in the atmosphere, and it can vary significantly depending upon temperature, geography, weather, altitude, etc. The measure of humidity is generally expressed in the form of percentage relative humidity (% RH) which is the ratio between partial pressure of water vapor in an air–water mixture to the saturated vapor pressure of water at a given temperature. An example from everyday life, where humidity can influence friction behavior is a touchscreen. While swiping a finger on a touchscreen, one can notice the difference in the force applied by the finger to initiate motion depends on the sweatiness of the finger.

Advanced materials and coatings such as diamond like carbon (DLC), polymer components (ABS, nylon, polycarbonate, etc.) are expected to perform seamlessly in all conditions from the outback of Australia, as well as in humid Singapore. Therefore, for optimizing performance, efficiency, or even the feel of materials and systems at different humidity levels, model scale tribometric investigations can offer a quick and reliable means of evaluating and understanding the tribosystem of interest.

2. METHODOLOGY

Tribological tests were carried out on a Modular Compact Rheometer (MCR 702) based Tribometer, (MCR Tribometer), from Anton Paar. The tribometer was equipped with a convection temperature device, CTD 180 Humidity Ready. The chamber of this device is designed to facilitate precise control of temperature, and simultaneously regulate the humidity around the test specimen. Illustrations of the CTD chamber along with the ball-on-three-plates (T-BTP) setup are shown below in Figure 1. The specimen set for each test consisted of one ball and three plates. The material used for the specimen is provided below in Table 1.

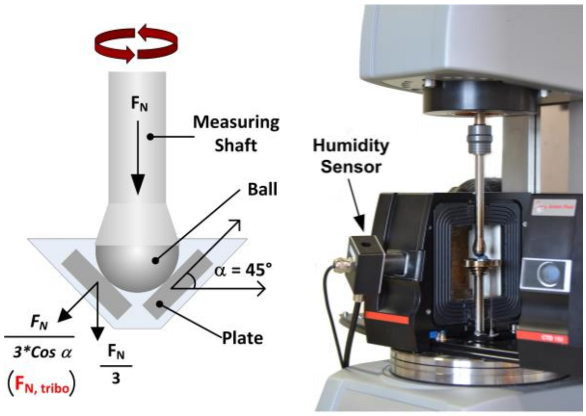

Figure 1. Detailed schematic of the ball-on-three-plates setup (left) and overview of the CTD chamber (right).

Table 1 Tested material.

Ball (∅ 12.7 mm)	**Plates (6 mm x 15 mm x 3 mm)**
1.4401 Steel	Polyamide 6.6 (*PA6.6*)
(AISI 316)	Polyoxymethylene (*POM*)

Determination of limiting friction and the break-away torque values of a system involve a simple principle. When at rest, the static friction between the bodies inhibits any relative motion, unless acted upon by an external force that exceeds this frictional resistance. Therefore, the applied force − in this case, the torque applied to the motor which in turn rotates the measuring shaft − is gradually increased and the resulting deflection or the sliding distance is measured. The moment the applied forces exceed the break-away forces, the system shows a sudden and substantial increase in the displacement of the shaft. While the principle in itself is simple, its execution requires precise control of the applied forces along with the ability to observe and record changes in the deflection angle of the shaft in the nano- to microscale range. Modern rheometers adapted for tribological tests offer an ideal combination of all the above features.

During the tribological test, the measuring shaft is lowered until the ball comes into contact with the plates. The maximum load here is restricted to 0.1 N to avoid shock loading. The load is then gradually increased to the predetermined value of 5 N. The system is then held at the test load for 15 minutes to allow it to relax. The torque is then increased logarithmically from 0.01 to 50 mN.m. At least three tests were carried out with each system at three different humidity levels, i.e., 5%, 30%, and 70% RH.

3. TEST RESULTS

The test results are presented below in Figure 2 in the form of graphs depicting the change in sliding distance as a function of applied torque. The applied torque works to slide the ball against the plates, while the frictional resistance impedes the motion. Macroscopic motion is only achieved once the applied torque overcomes the frictional resistance.

The break-away points in each of the curves in Figure 2 indicate the starting point of macroscopic motion of the ball against the plates. Until that point, the increase in the sliding distance with increasing torque is in the sub-micron to micron range. This increase is attributed to the elastic and plastic deformation of the system prior to the onset of macroscopic motion. Once the applied torque reaches the break-away point, the sliding distance shoots from a couple of micrometers to a few millimetres. This shift in the sliding distance by three orders of magnitude indicates the onset of macroscopic motion between the ball and the plates. The coefficient of friction recorded at the break-away point corresponds to the limiting friction of the system.

For both the systems, i.e., Steel vs. PA6.6 and Steel vs. POM, the break-away torque increases with increasing humidity. However, the increase is much more significant in the case of Steel vs. PA6.6 system. This is due to the fact that PA6.6 is more hygroscopic than POM. This leads to a greater adsorption of water molecules at the surface of the PA6.6 specimen. The average limiting friction for each of the systems at different humidity levels is presented in Table 2. The values of the standard deviation mentioned in the brackets shows that the results obtained here are highly reproducible.

Table 2 Values of limiting friction.

Relative Humidity	Coefficient of Limiting Friction [-]	
	Steel vs. PA6.6	*Steel vs. POM*
5 % RH	0.11 (± 003)	0.08 (± 004)
30 % RH	0.15 (± 005)	0.10 (± 004)
70 % RH	0.19 ((± 007)	0.12 (± 0)

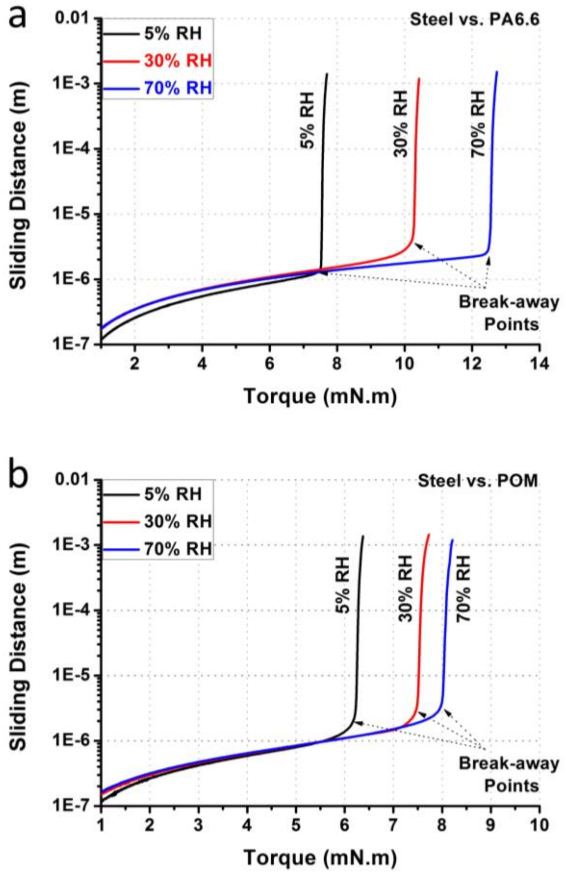

Figure 2. Plots depicting sliding distance as a function of increasing torque for (a) POM–steel system and (b) PA6.6–steel systen. The torque value at the break-away points is the break-away torque of the system.

4. SUMMARY

Tribometric tests were carried out on Steel–POM and Steel–PA6.6 tribopairs to study the influence of humidity on their static–friction behavior. Results show that the limiting friction at the contact for both systems increases with increasing humidity. However, due to its greater hygroscopicity, the frictional behavior of PA6.6 shows a greater dependence on humidity than POM. Additionally, the tests show that the methodology adapted here offers a unique possibility of studying the influence of humidity on the tribological characteristics of a system.

5. REFERENCES

[1] J. Takadoum, *Materials and Surface Engineering in Tribology*, John Wiley & Sons, Ltd., 2010 DOI: 10.1002/9780470611524.

[2] B. Bhushan, *Nanotribology and Nanomechanics: An Introduction*, 2nd ed.). Springer Publishing Company Incorporated, 2008, ISBN:3540776079 9783540776079.

[3] Donald H. Buckley, Editor(s), Tribology Series, Volume 5, Elsevier, 1981, ISSN 0167-8922, ISBN 9780444419668.