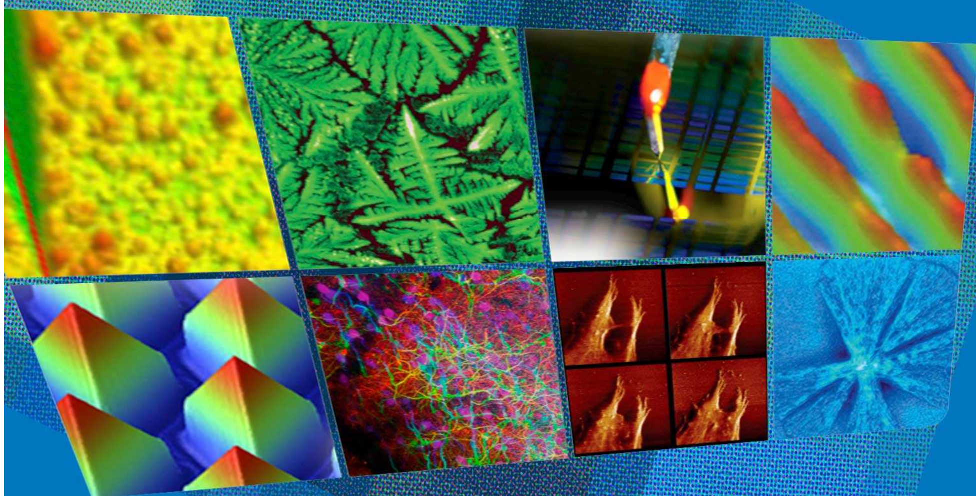
Automotive Tribology

Nianqing Li   Product Specialist (Tribology and Mechanical Testing)



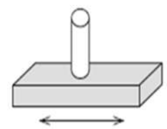
Atomic Force Microscopy
3D Optical Microscopy
Fluorescence Microscopy
Tribology
Stylus Profilometry
Nanoindentation

Bruker Nano Surfaces Division

Innovation with Integrity

Tribology Basics

- Tribology is the study of friction, wear, and lubrication of interacting surfaces in relative motion
- Tribology results from the need to know how interacting materials and lubricants behave under various Motions, Speeds, Loads, and Environments
- Tribology testing is designed to mimic real world environments

Typical Tribology Tests	*Model*	*Description*
Ball/Pin-on-Disk		Sliding Wear and Friction Behavior Between a Static Pin (Area Contact) or Ball (Point Contact) and a Rotating Surface
Ball/Pin-on-Plate		Sliding Friction and Wear Behavior Between a Static Pin (Area Contact) or Ball (Point Contact) and a Linear Displacing Surface
4-Ball		High-Pressure Lubricant/Grease Characterization Test
Block-on-Ring		Sliding Wear and Friction Behavior Between a Block and a Radial Ring (Line Contact)
Disk/Ring-on-Disk		Sliding and/or Rolling Wear and Friction Behavior Between Two Disk or Ring Surfaces (Area Contact) Sharing the Same Axis

Tribology phenomenon in automobile

- Automobile contains engine, chassis, body, electrical equipment. Engine has fuel supply, lubrication, cooling, ignition, starting system.
- Tribology phenomenon can be found on the counterparts with motion or trend of motion. Some of them benefit, whereas some not.

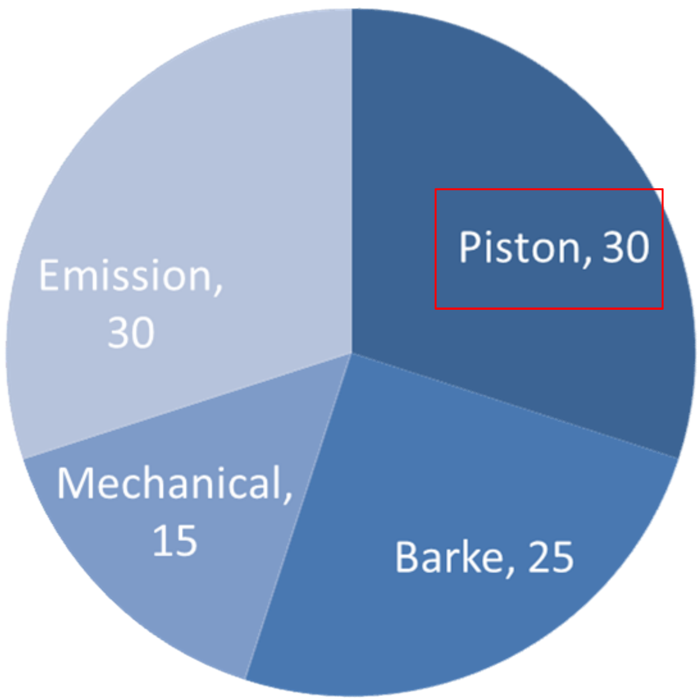
- The surrounding environment (ground , air) has friction with automobile. The speed will also affect the tribology properties.

Application Examples

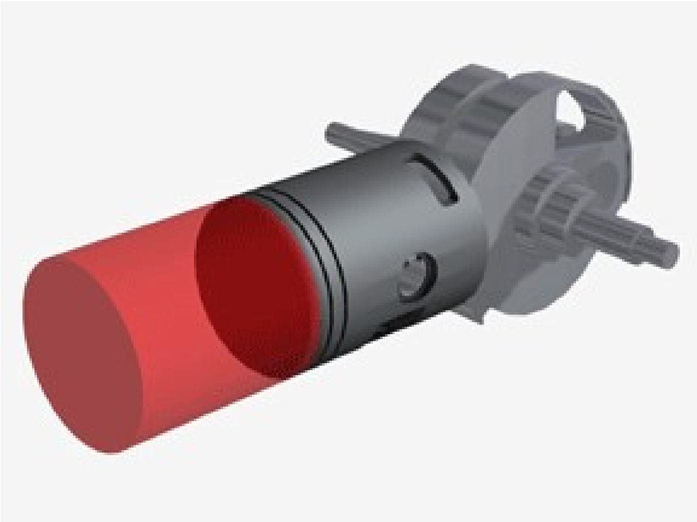
1. Friction and wear of piston and cylinder
2. Friction of clutches
3. Friction and wear of thrust washer
4. Adhesion of coatings
5. Anti-scratch of glasses
6. Hot hardness

Application 1: Friction and wear of piston and cylinder (ASTM G181)

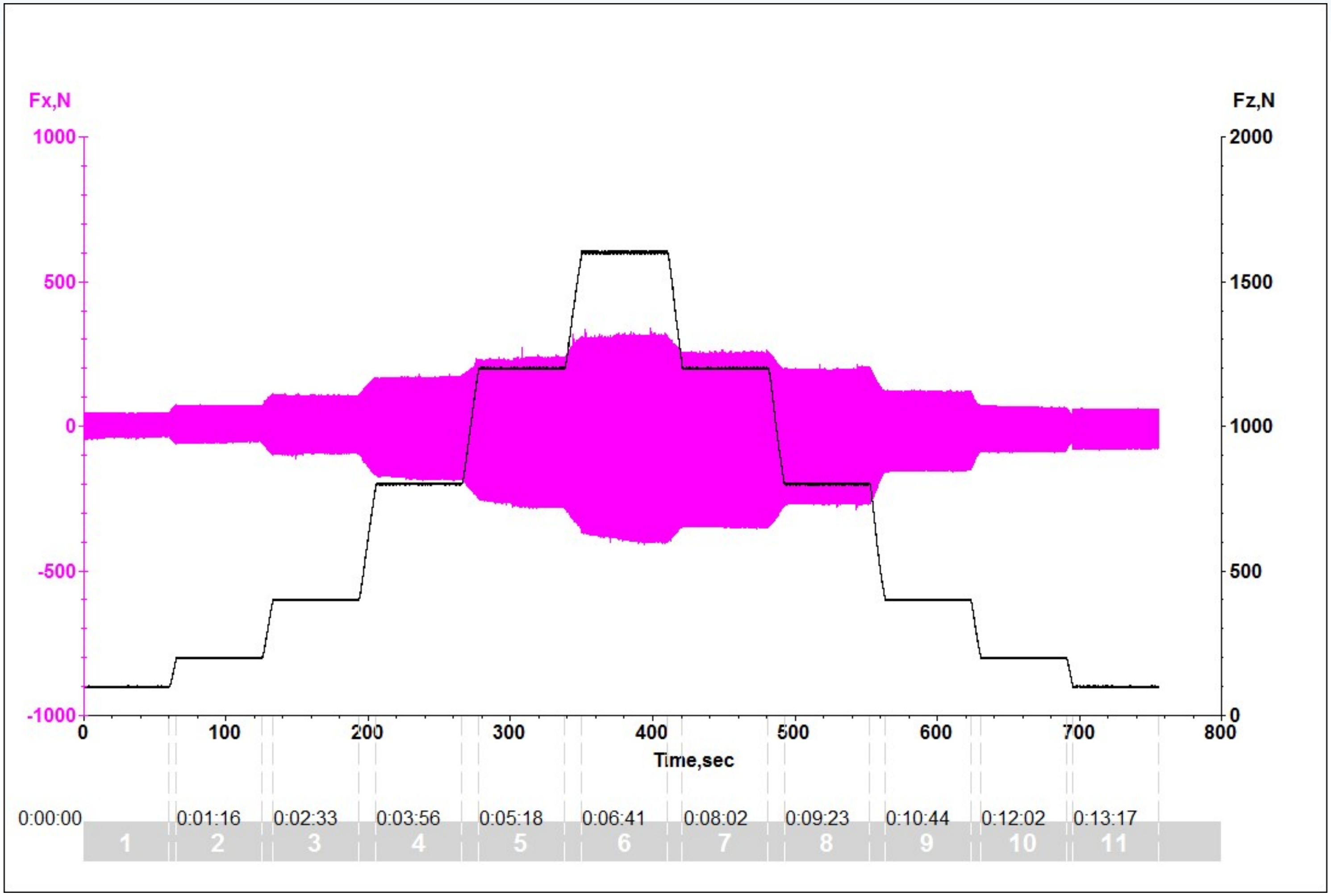
Energy consumption in combustion engine



- Piston is one of the most important parts of engine, which contacts with cylinder airtightly.
- High requirements are needed for piston and cylinder, such as thermal conductivity, mechanical performance under high temperature, good running-in and good wear resistance.

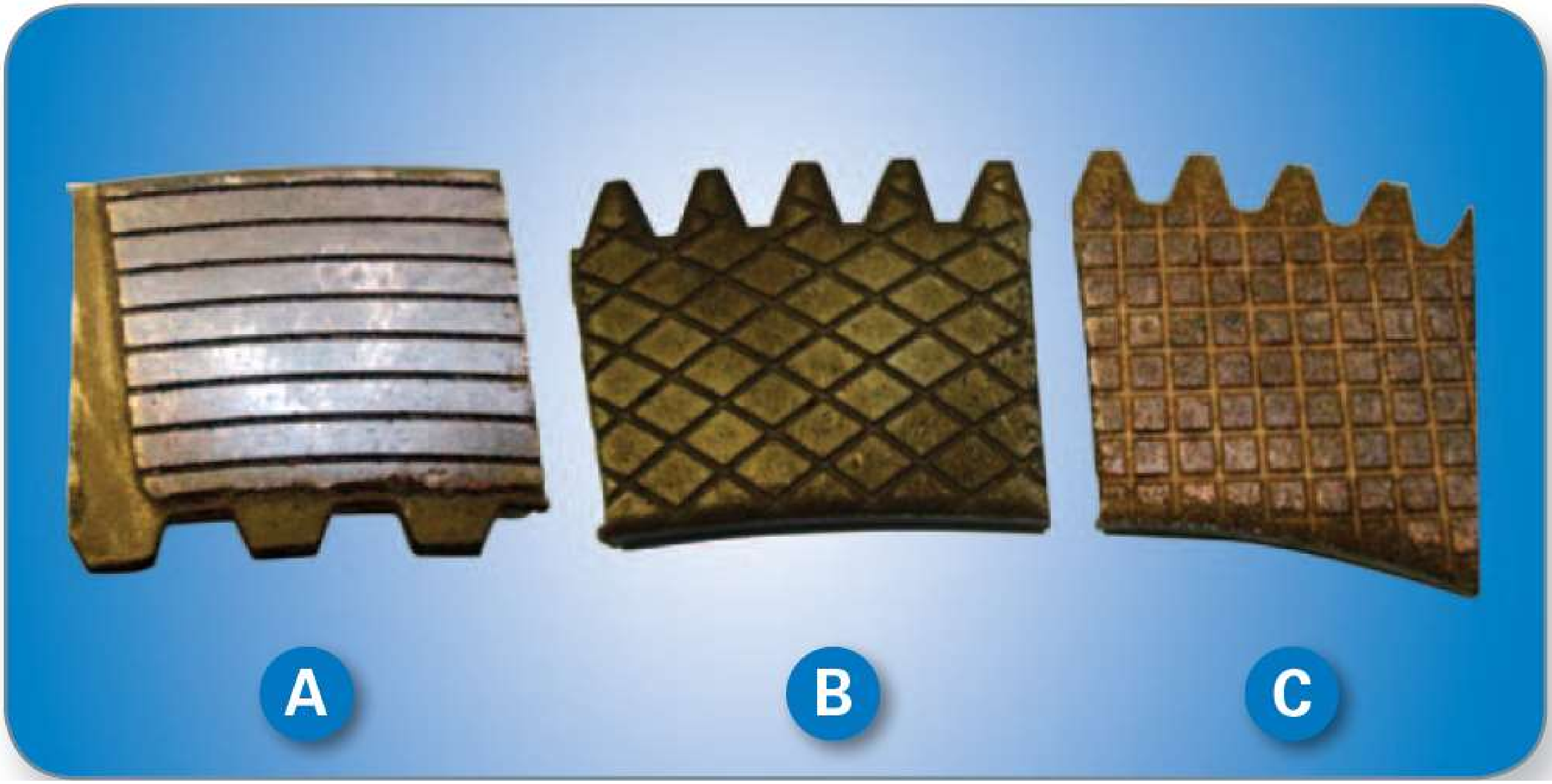


Application 1: Friction and wear of piston and cylinder (ASTM G181)



Application 2: Friction of different clutches
Screening clutch materials

- A. Concentric pattern; B. Diamond pattern; C. Square pattern.



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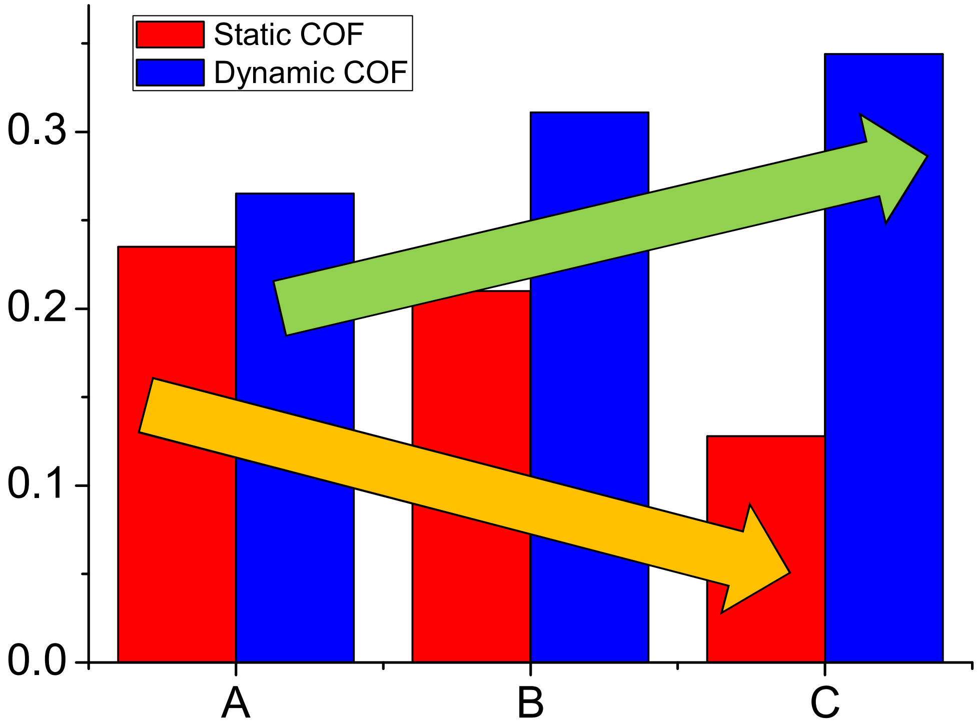
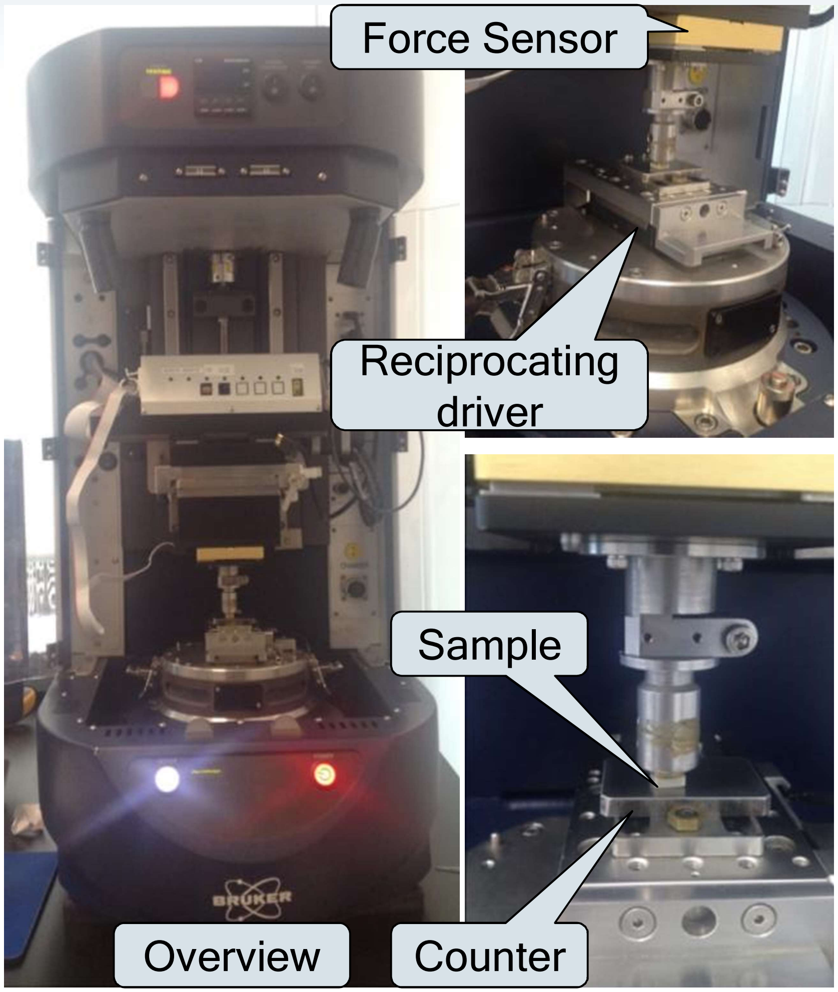


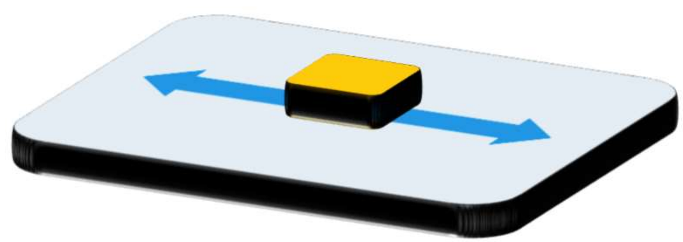
A. Concentric pattern; B. Diamond pattern; C. Square pattern.
COF: coefficient of friction

Application 3: Friction of Thrust Washer Setup

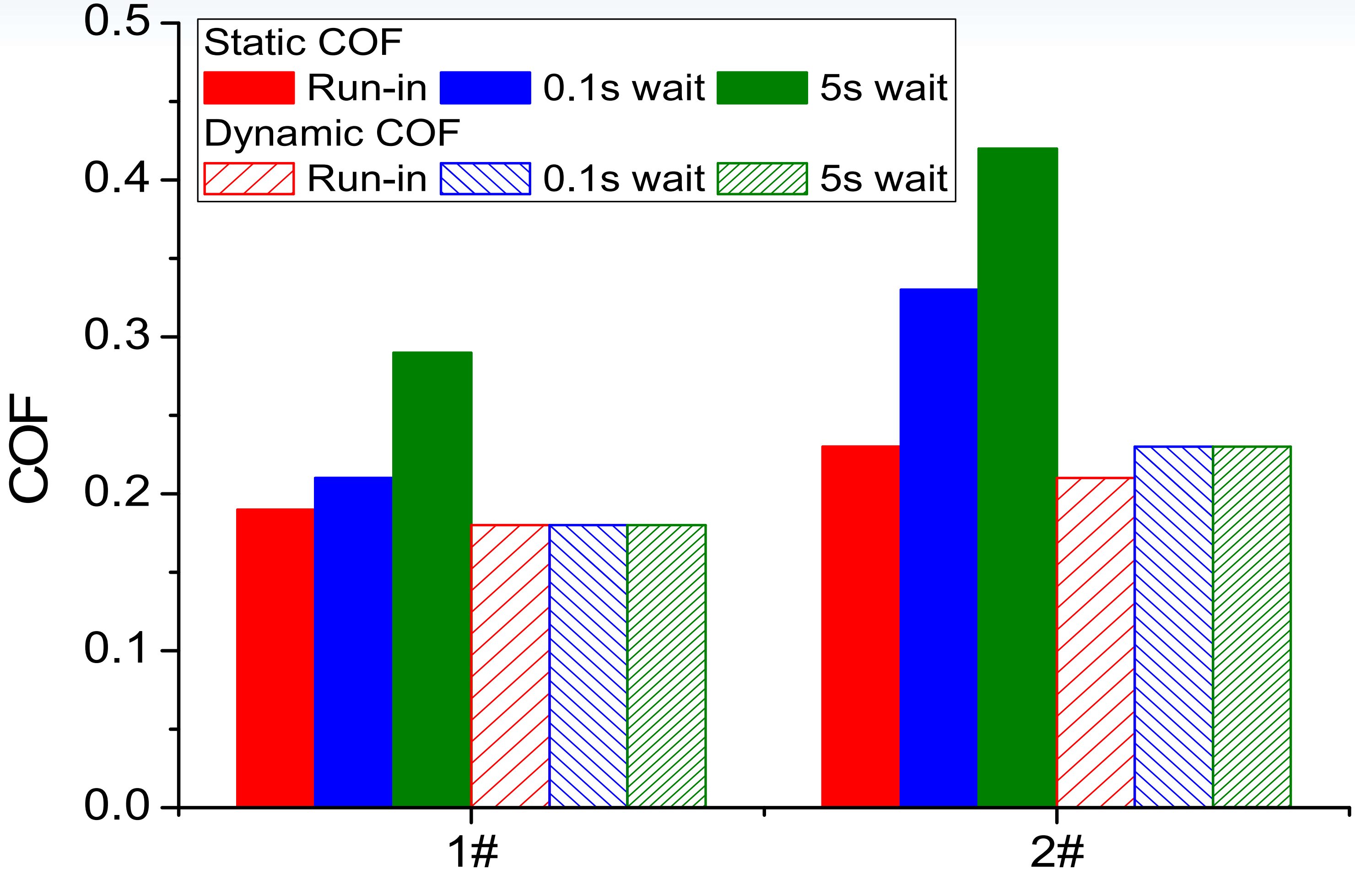


- Ambiance.
- Acquisition rate: 7kHz

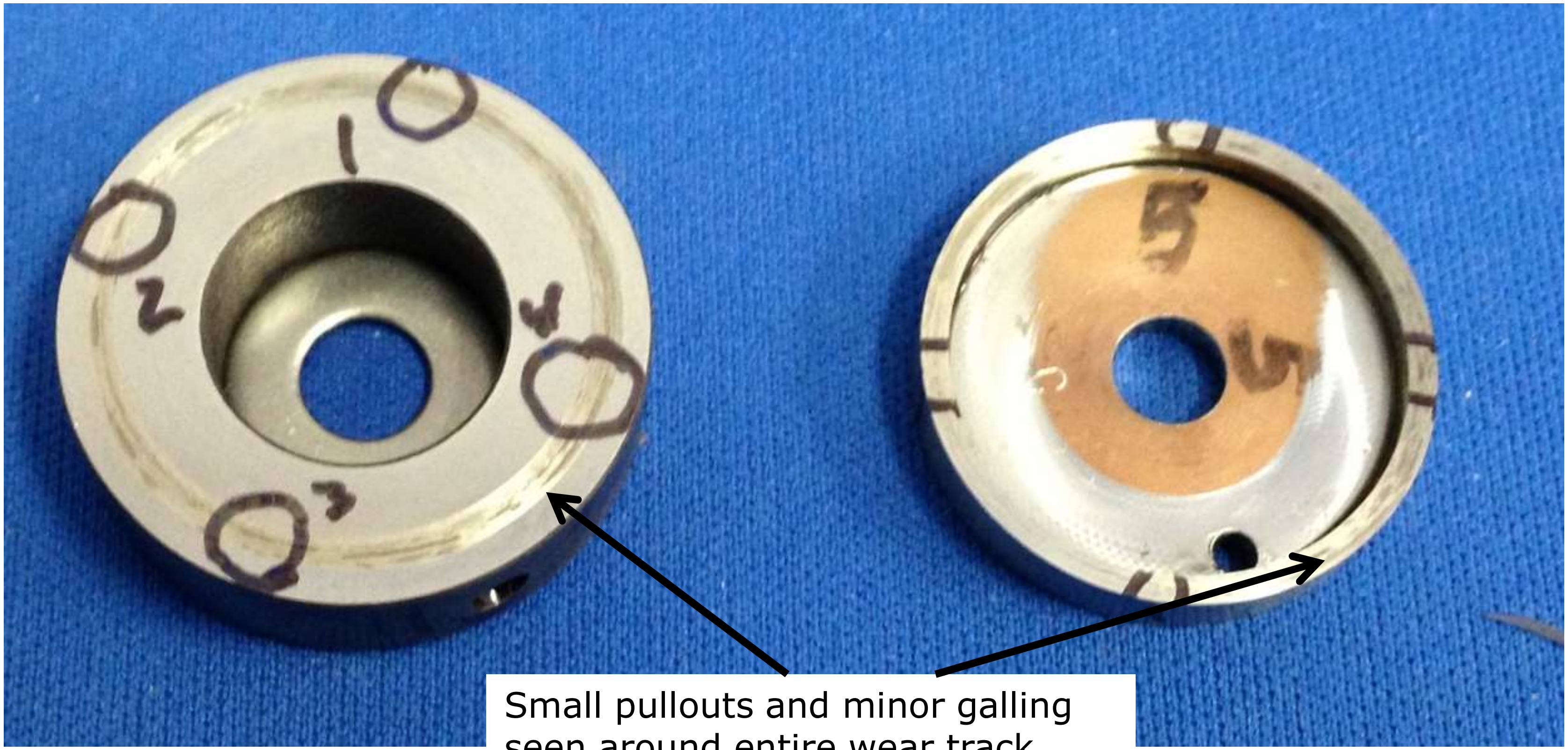
	Run-in	Test
Load/N	50	50
Frequency/Hz	1	1
Stroke/mm	1	1
Wait time/s	0	0.1 and 5
Duration/min	15	5



Application 3: Friction of Thrust Washer Results

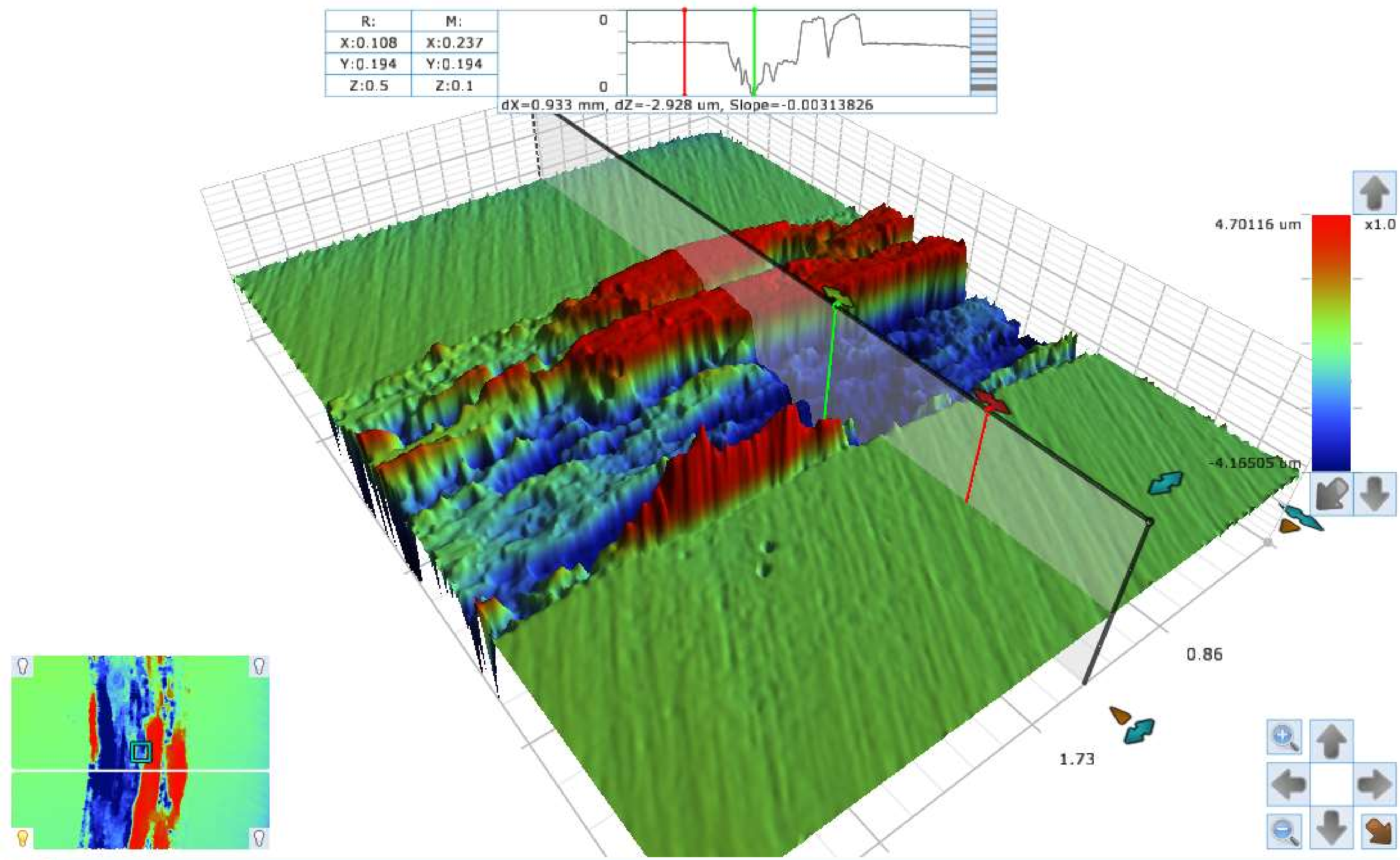


Application 3: Friction of Thrust Washer Sample after tests



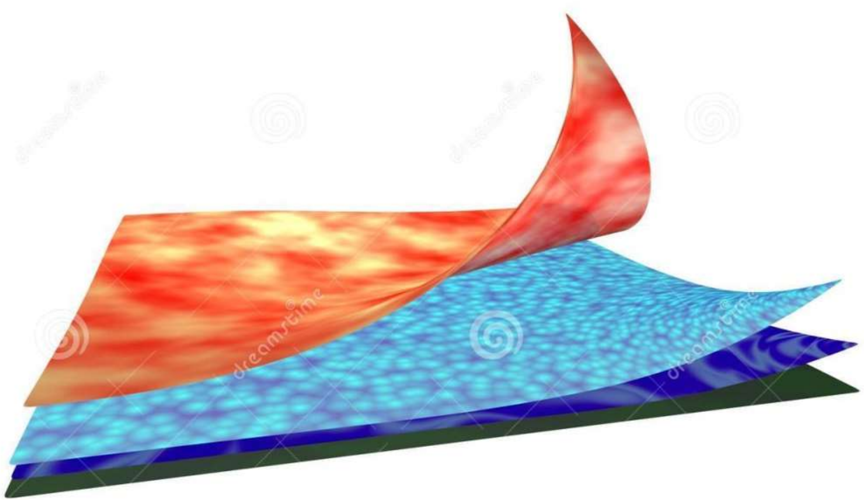
Small pullouts and minor galling seen around entire wear track, both samples

Application 3: Friction of Thrust Washer Wear

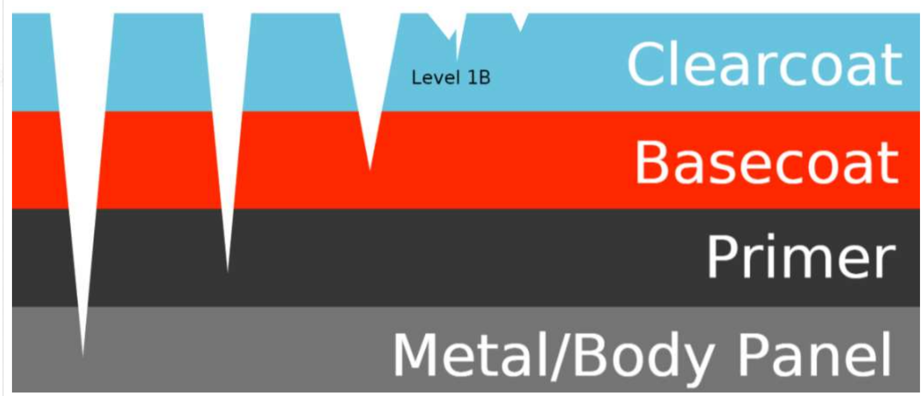


Application 4: Adhesion of coatings

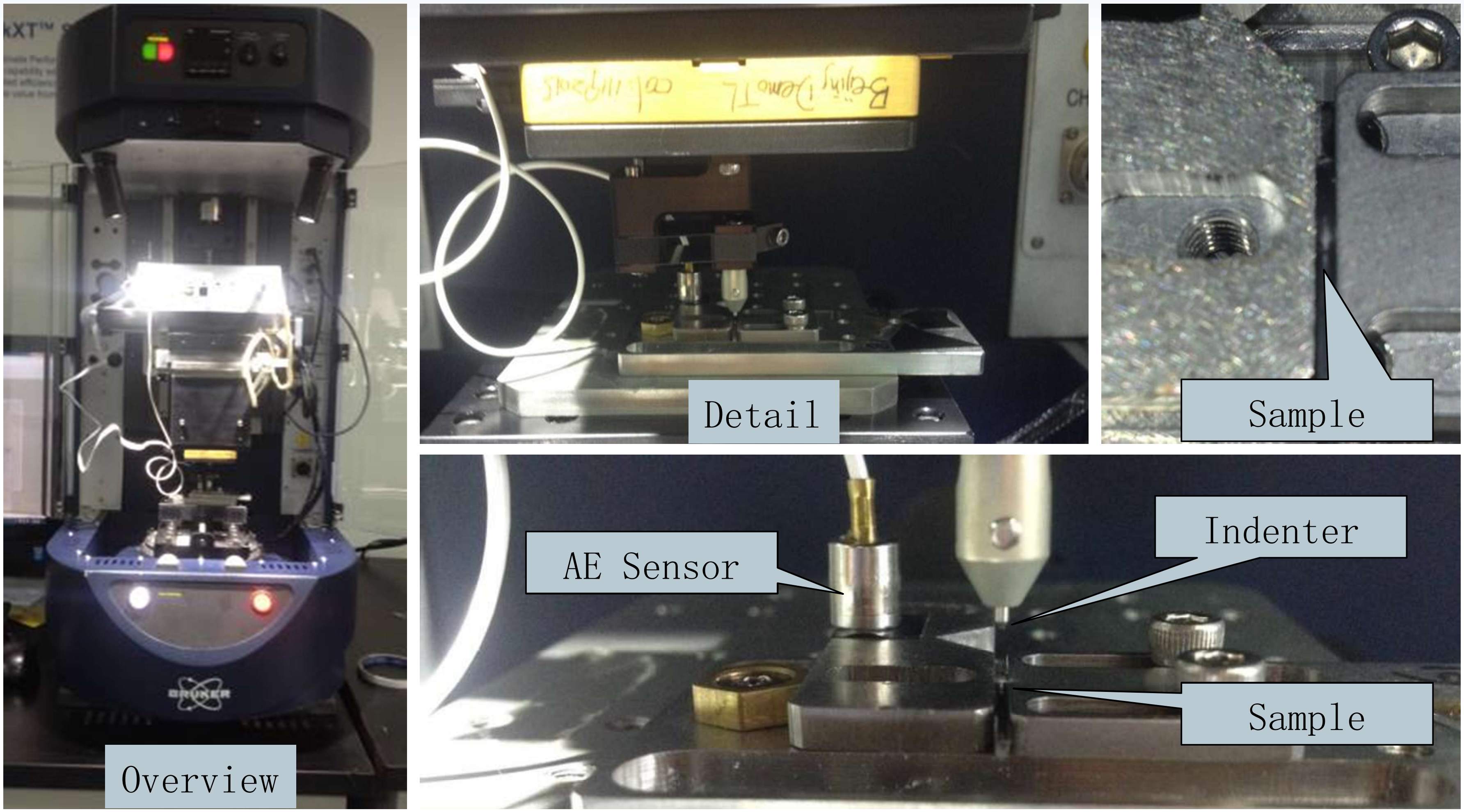
- Paints and films are coated broadly on automobile for protection, decoration and other functions. Novel coatings are developping continuously.
- Scratch test is used to measure the adehsion, anti-scratch and anti-mar properties of various coatings complying with standards.



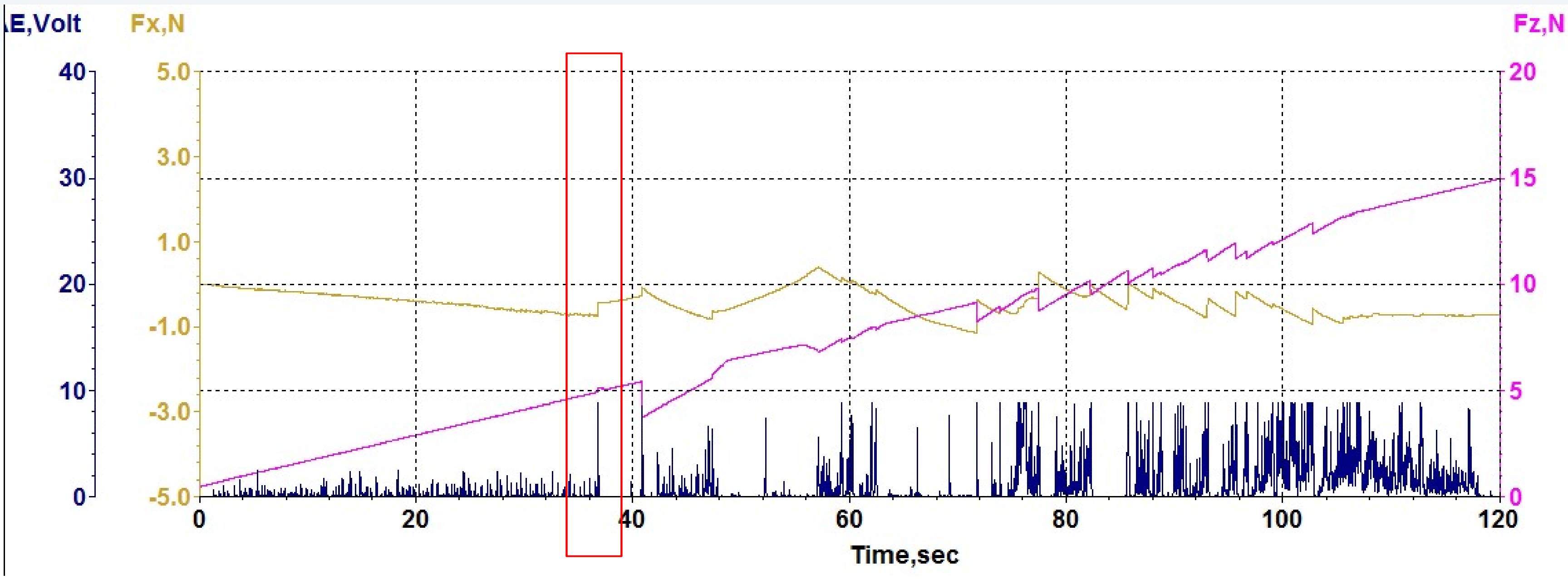
Scratch test



Application 4: Adhesion of coatings
Scratch test following ASTM C1624

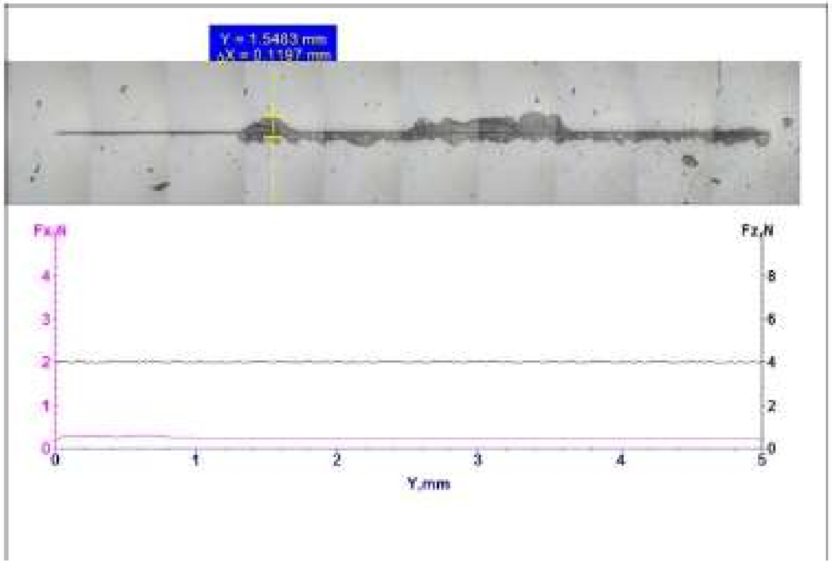


Application 4: Adhesion of coatings Scratch test following ASTM C1624

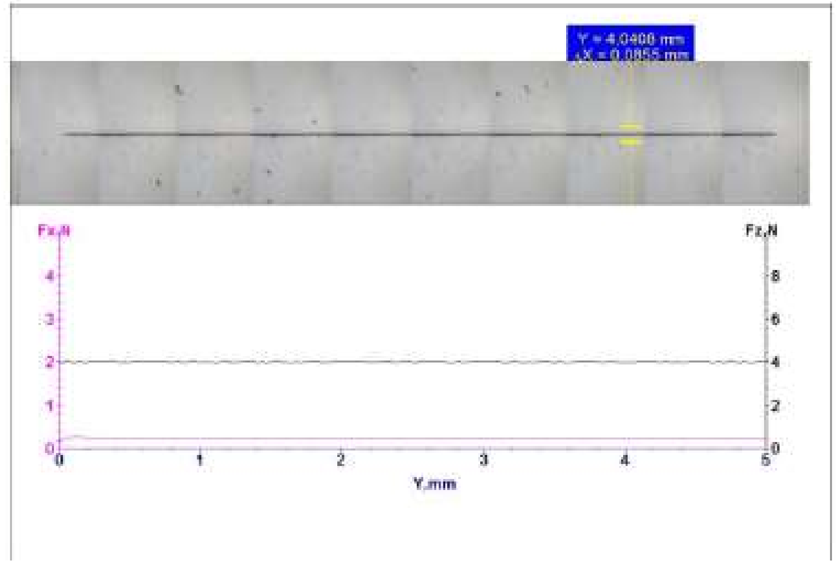


- The red frame shows Fx changed suddenly, which indicates the failure of coatings on piston ring. The spike of the acoustic emission confirms
- Adhesion is 5N.

Application 5: Anti-scratch Constant Load - Glass Samples



Specimen 1



Specimen 2

Tool: Knoop Indenter

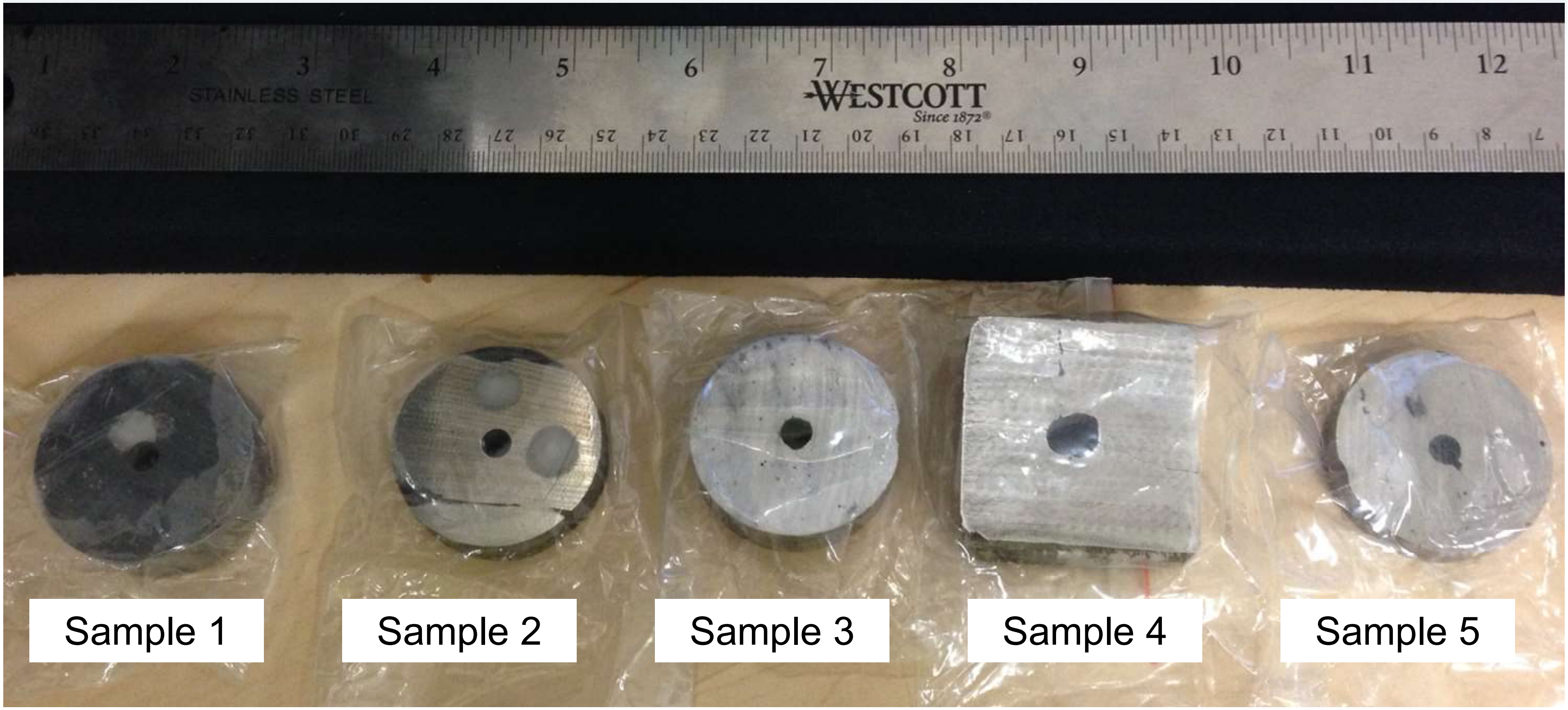
Scratch Parameters: 5 mm at 50µm/s; Load 4N (Constant)

Hot Hardness

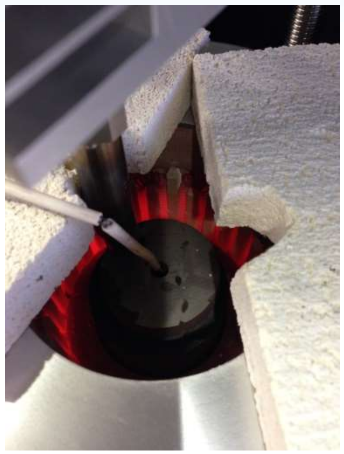
Description of HBB Method

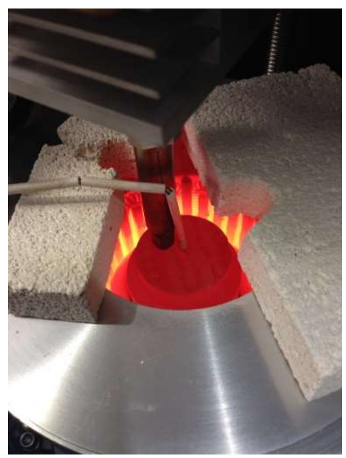
- Based on Rockwell Hardness method*:
  - 10 kg minor load applied – Establishes Reference Position
  - 50 kg major load applied – Results in permanent plastic deformation
  - 10 kg minor load is re-applied and height difference from original loading is determined
    - (Eliminates contribution from elastic deformation)
  - Calculation is based on: 100 – Δheight at minor load (in units of 2 μm)
- Designation as follows: $HBB^{3.2}_{50}$ ← Ball Diam. in mm; ← Major Load in kg
- Al_2O_3 ball used for high temperature stability

Example: Weld-Deposited Samples - As Received



Example Testing Images (various)



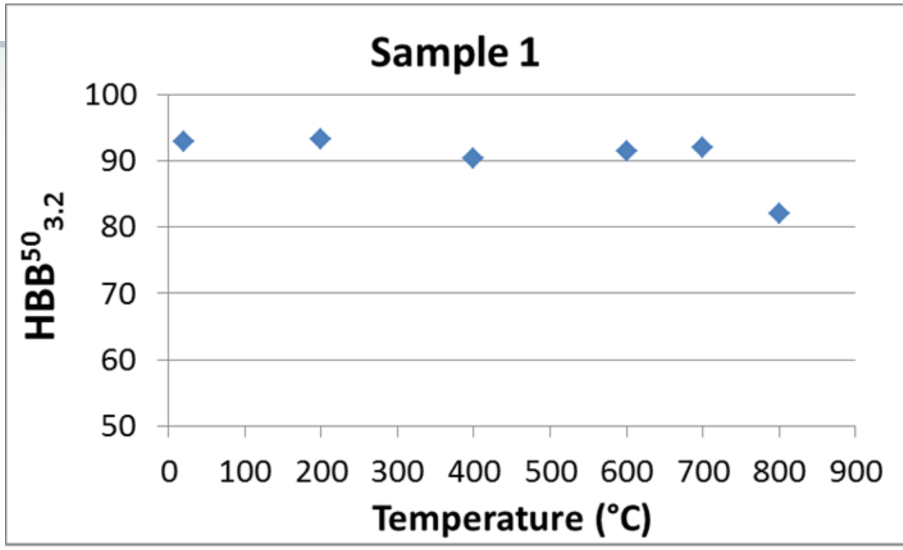


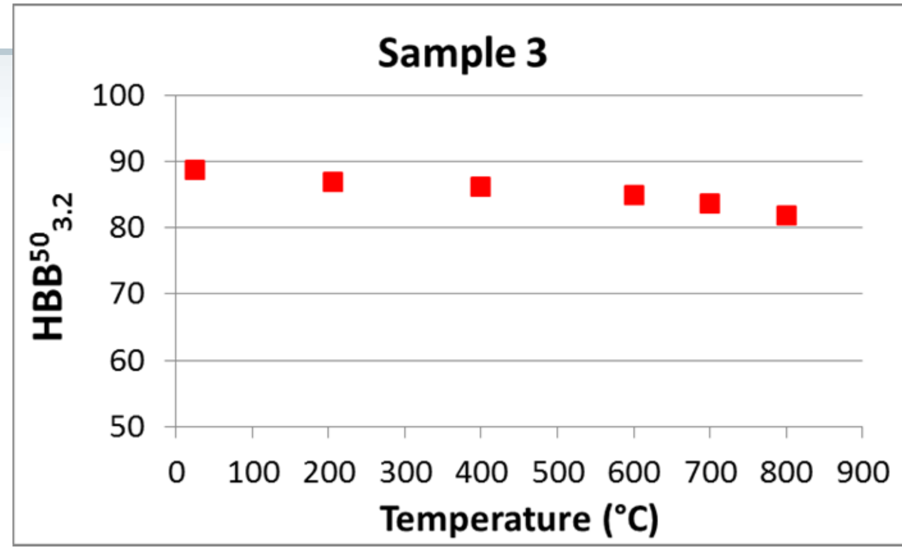
Test Results: Tabular

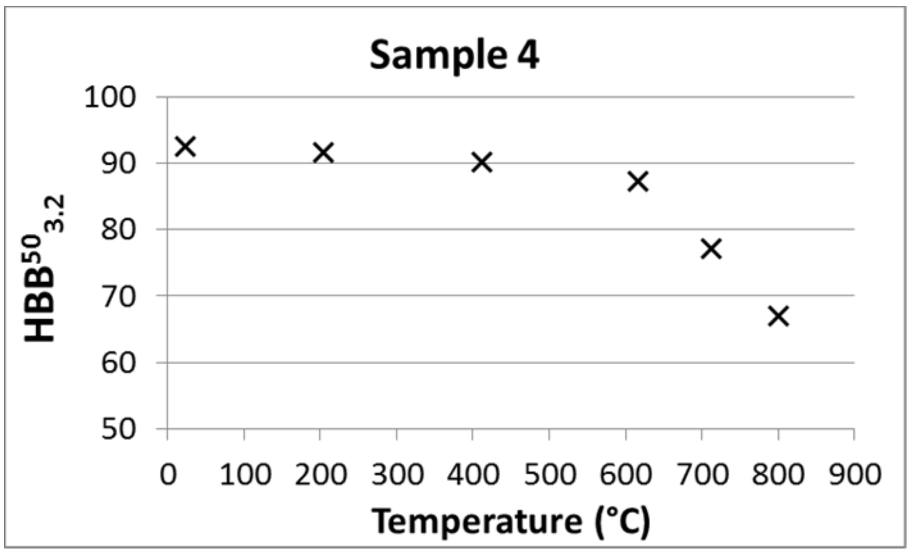
Average and Standard Deviation of a minimum of 5 measurements per temperature

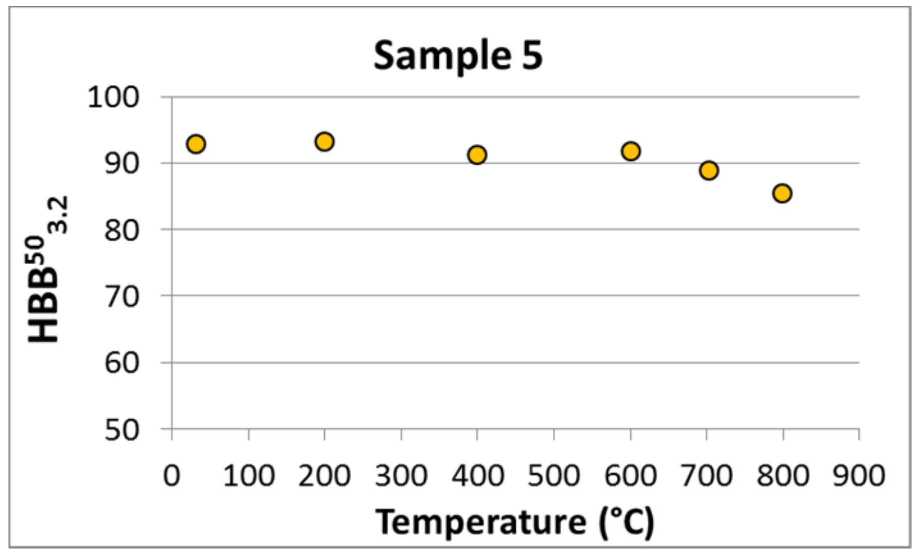
Sample ID	RT		200°C		400°C		600°C		700°C		800	
	HBB	SD	HBB	SD	HBB	SD	HBB	SD	HBB	SD	HBB	SD
1	92.9	1.5	93.2	0.9	90.4	2.9	91.4	0.9	92.0	2.7	82.0	2.8
3	88.7	2.1	87.0	1.4	86.1	1.5	84.9	3.7	83.7	5.2	81.8	3.2
4	92.5	1.9	91.6	0.6	90.1	1.4	87.2	2.4	77.2	2.2	67.0	5.1
5	92.9	1.6	93.2	0.8	91.3	1.7	91.8	2.9	88.9	2.7	85.4	2.2
Sample ID	**RT**		**150°C**		**250°C**		**350°C**		**400°C**			
	HBB	SD	HBB	SD	HBB	SD	HBB	SD	HBB	SD	HBB	SD
2	92.9	2.7	92.4	0.7	94.3	0.5	92.8	0.5	94.4	0.5	93.3	1.5

Results - Graphical: Samples 1, 3, 4, 5
(Max Temperature 800° C)

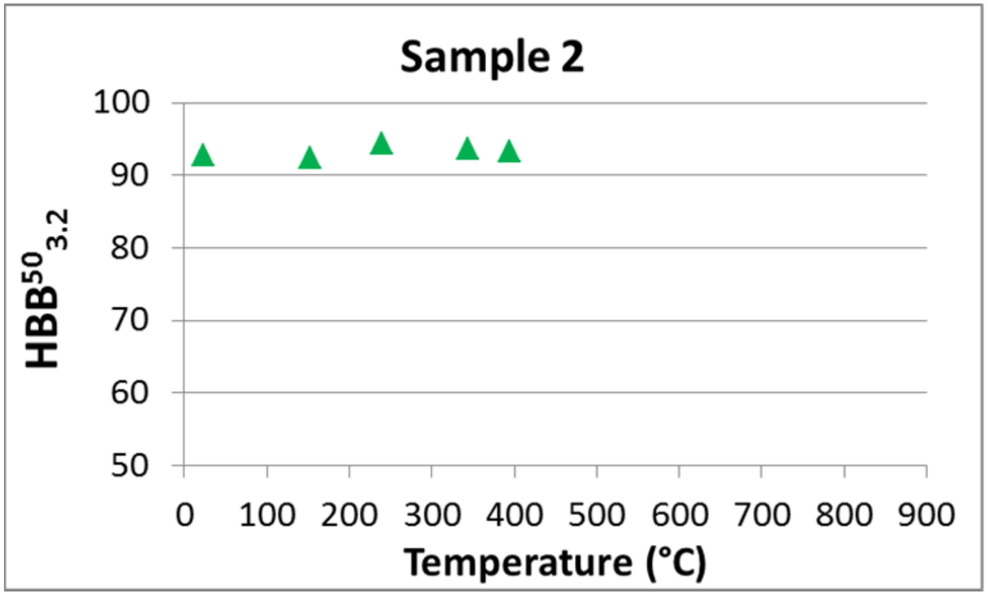






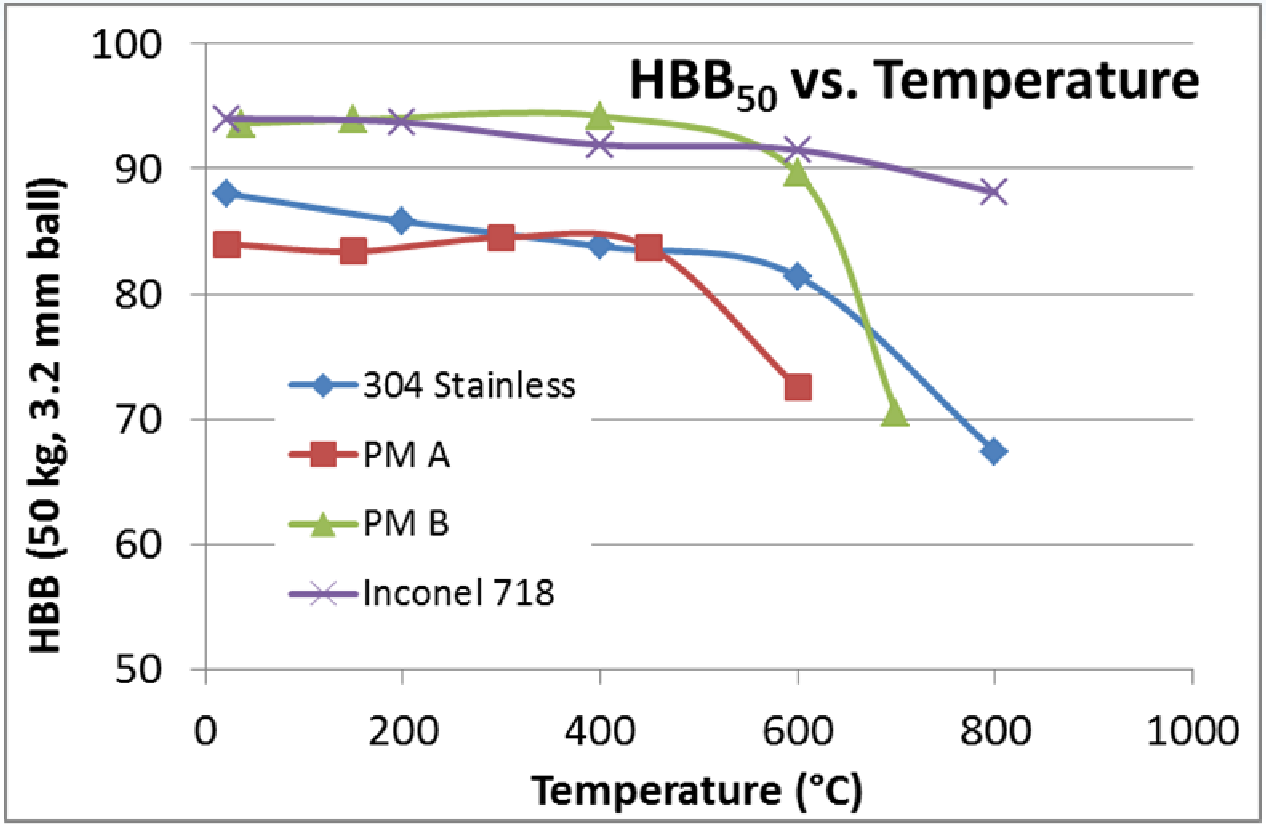


Results - Graphical: Sample 2 (Max Temperature 400° C)



Data Example 2: Powder-Metal Samples

$HBB_{50}^{3.2}$



PM-A would be a suitable substitute for 304 SS at or below 400° C

PM-B would be better than 304 SS up to 700° C, and equal to Inconel 718 up to 600° C

Inconel 718 is best choice at 800° C

Sample of Automotive Papers

Y. Zhang, J. Chen, W. Lei, R. Xv, *Effect of laser surface melting on friction and wear of AM50 magnesium alloy*, Surface and Coatings Technology, v. 202, issue 14, April 15, 2008, pp.3175-3179.

J.I. Weon, *Quantitative determination of mar-resistance of high gloss coatings*, Macromolecular Research, (2012), pp.1-4.

R.P. de Castro Costa, F.R. Marciano, D.A.L. Oliveira, & V.J. Trava-Airoldi. *Enhanced DLC wear performance by the presence of lubricant additives*. Materials Research, (2011), v.14, no.2, pp. 222-226.

A. Amanov, I.S. Cho, & D.E. Kim, *Effectiveness of high-frequency ultrasonic peening treatment on the tribological characteristics of Cu-based sintered materials on steel substrate.* Materials & Design, v.45, March 2013, pp.118-124.

D. Nedelcu, *Investigation on microstructure and mechanical properties of samples obtained by injection from Arbofill.* Composites Part B: Engineering, v.47, April 2013, pp. 126-129.

F. Zhou, Y. Wang, H. Ding, M. Wang, M. Yu, & Z. Dai, *Friction characteristic of micro-arc oxidative Al2O3coatings sliding against Si3N4 balls in various environments*. Surface & coatings technology, (2008), v.202, no.16, pp. 3808-3814.

J.I. Weon, S.Y. Song, K.Y. Choi, S.G. Lee, & J.H. Lee. *Quantitative determination of scratch-induced damage visibility on polymer surfaces*. Journal of materials science, v.45, no.10, (2010), pp. 2649-2654.

Z.H. Cai, Y.L. Di, & P. Zhang, *Microstructure and tribological property of Cr/CrN nano-multilayer film deposited on piston ring*. Journal of Shenyang University of Technology, v.33, no.4, (2011), pp. 375-381.

T.W. Seo, & J.I. Weon, *Influence of weathering and substrate roughness on the interfacial adhesion of acrylic coating based on an increasing load scratch test.* Journal of Materials Science, v. 47, no. 5,, (2012), pp. 2234-2240.

R. Gonzalez, A.H. Battez, D. Blanco, J.L. Viesca, & A. Fernández-González. *Lubrication of TiN, CrN and DLC PVD Coatings with 1-Butyl-1-Methylpyrrolidinium tris (pentafluoroethyl) trifluorophosphate*. Tribology Letters, v. 40, no. 2, (2010), pp. 269-277.

M.A. Islam, & Z. Farhat. *Wear of A380M Aluminum Alloy Under Reciprocating Load*. Journal of materials engineering and performance, (2010). v.19, no.8, pp.1208-1213.

A.V. Zolotov, G.N. Kuz'mina, V.A. Zolotov, R.V. Bartko, A.G. Sipatrov, & O.P. Parenago, *A composition of organic hetero compounds as an antioxidant and antiwear additive for mineral lubricating oils.* Petroleum Chemistry, (2013), 5v.3, no.4, pp.262-266.

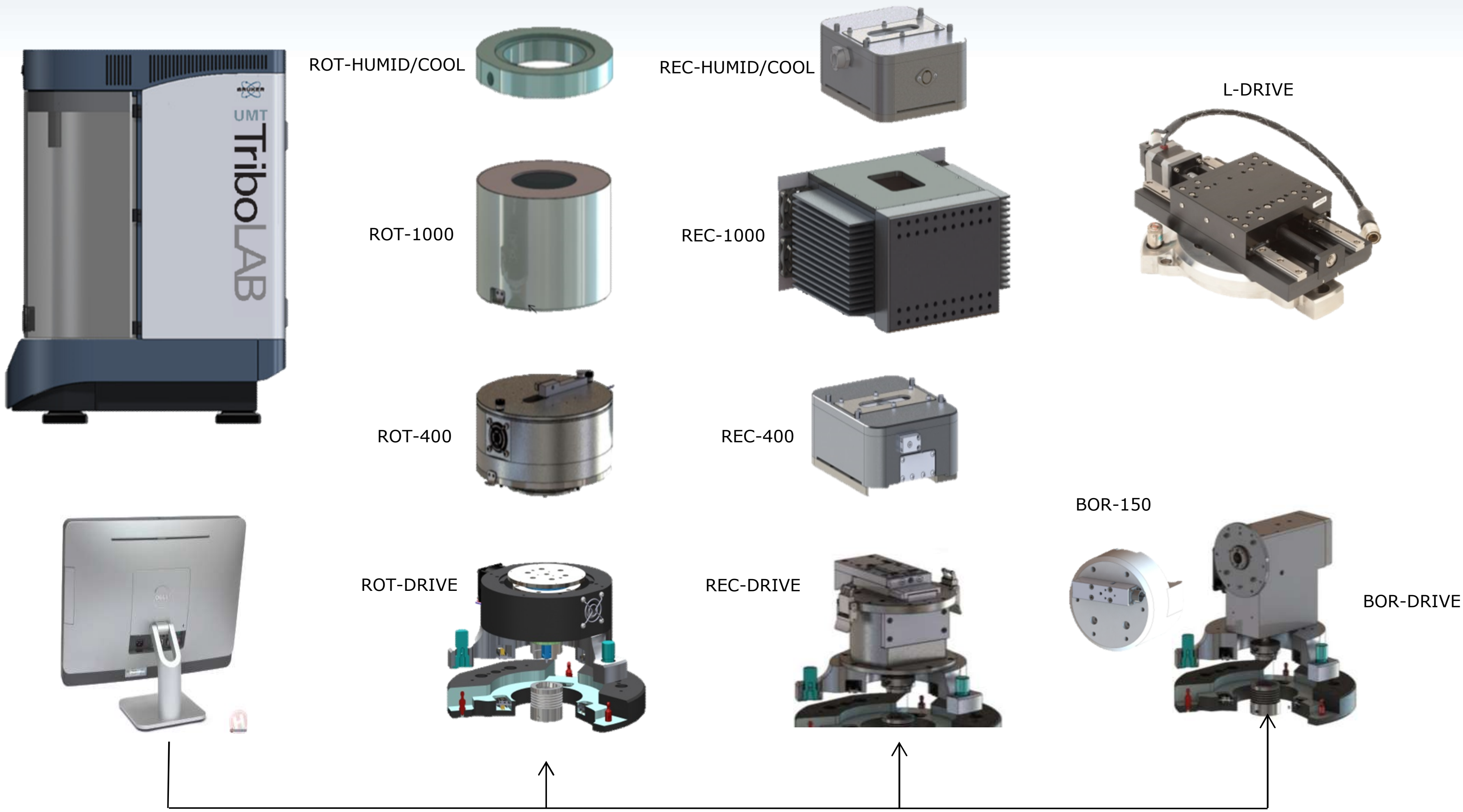
M.T. Siniawski, A. Martini, S.J. Harris, & Q. Wang. *Effects of lubrication and humidity on the abrasiveness of a thin boron carbide coating.* Tribology Letters, (2005), v.18, no.2, pp.185-195.

S. Yoon, M. Shin, W. Lee & H. Jang. *Effect of surface contact conditions on the stick¯slip behavior of brake friction material.* Wear, (2012), v.294, pp. 305-312.

J.Y. Jang, & M.M. Khonsari, *Linear Squeeze Film with Constant Rotational Speed*. Tribology Transactions, (2008), v.51, no.3, pp. 361-371.

UMT TriboLab: R&D Tool for Tribology

4 lower drives and 9 environmental chambers



Summary

Things to measure	Environment	Applications
Friction	High Temperature 1000C	Efficiency of Mechanical Systems
Wear	Low Temperature: -25C	Life Time of Mechanical Systems
Adhesion (Coating and film)	Humidity 5-85%	Material Screening
Hardness	Liquids/Lubricants /Corrosion	Lubricant Screening
Modulus	Vacuum（10^{-5}Torr）	CMP Process Development

Q&A

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