EP Laboratories, Inc.

... the solution to your testing needs

Analytical Report Compilation

TRB-L 160913 – RFG, TG PPS
TRB-L 161214 – RFG Impact Modified, AU (Amodel Unfilled), PAEK GF40
TRB-L 170310 – AF GF30 (Amodel Filled, 30% Glass)
TRB-L 170320 – Steel Sucker Rod Wrench Square
TRB-L 210706 – Polyketone, Unfilled
TRB-L 230407 – Polyketone, Glass-Filled at 5%, 10%, 15%, 20%, 30% Filler Level

Method:

Linear Reciprocating Ball-on-Flat Wear Testing

Instrument:

CSM Instruments 'Pin-On-Disk" Tribometer SN: 18-281
Linear Module SN: 1-120
Software: InstrumX v2.7, Software:
Mountains, by Digital Surf

Sample(s):

Summary Compilation Report

Authorized by:

Ethel Poiré
Director, Lab Services

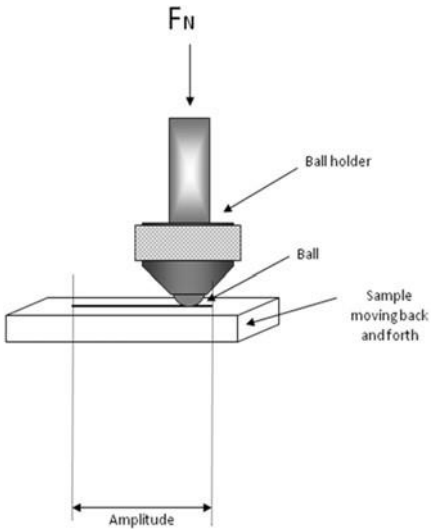
Rod Guide Materials - Linear Reciprocating Ball on Flat Wear Testing

Principle

This test method involves two specimens: a flat specimen and a spherically ended specimen (herein called “ball” specimen) which slides against the flat specimen. These specimens move relative to one another in a linear, back and forth sliding motion. The load is applied vertically downward through the ball specimen against the horizontally mounted flat specimen.[3]

Since this test method involves reciprocating sliding where changes in the sliding velocity and direction of motion occur during the test, constant velocity conditions are not maintained. Dimensional changes for both ball and flat specimens are used to calculate wear volumes and wear rates.[3]

Friction forces are measured during the test and may be used to assess changes in the contact conditions or the kinetic friction coefficient as a function of time.[3] The ball is mounted on a stiff lever, designed as a frictionless force transducer. As the flat specimen is moved back and forth, resulting frictional forces acting between the ball and the flat specimen are measured by very small deflections of the lever using an LVDT sensor. This simple method facilitates the determination and study of friction and wear behavior of almost every solid-state material combination, with varying time, contact pressure, velocity, temperature, humidity, lubrication, etc.



Standards and Practices

Testing was performed in accordance with ASTM G133 Procedure A. However, test is not in full compliance with the standard because:

- The ball radius is 3mm instead of 4.76mm
- The normal force is 10N and 30N instead of 25N
- The oscillating frequency is 1.6Hz and 0.6Hz instead of 5Hz
- The test duration is longer than 16min40s, however, the sliding distance is 100m
- Heat was applied
- Lubrication was applied

Instrument and Software

Test was performed with a Pin-on-Disk “Tribometer” from CSM Instruments, S/N 18-281 with “linear module” S/N 1120; software “InstrumX” version 2.7. Profiles were processed and analyzed with the surface analysis software “Mountains” from Digital Surf.

Specimens

#1 RFG Glass and Mineral Filled (Glossy Black)
#2 TG PPS Modified Glass and Mineral Filled taken from Rod Guide (Matte Grey)
#3 RFG Impact Modified (Glossy Black)
#4 AU Sample taken from Rod Guide (Similar to Amodel PPA Unfilled, Cream White)
#5 PAEK GF40 Sample taken from Rod Guide (Similar to PAEK GF40%, Tan Brown)
#6 AF GF30 Sample Taken from Rod Guide (Similar to Amodel PPA GF30%, Matte Black)
#7 KD 4320M Steel Sucker Rod Wrench Flat
#8 Polyketone, Unfilled
#9 Polyketone, 5% Glass Fiber Filled
#10 Polyketone, 10% Glass Fiber Filled
#11 Polyketone, 15% Glass Fiber Filled
#12 Polyketone, 20% Glass Fiber Filled
#13 Polyketone, 30% Glass Fiber Filled

Test Conditions and Parameters

The following test parameters were used:

	Setting #1	**Setting #2**
Applied normal force:	10.020 N	30.056 N
Stroke length:	10 mm	10 mm
Sliding distance:	100 m	100 m
Test duration:	2h 10 min	2h 10 min
Max linear speed:	0.02 m/s	0.02 m/s
Frequency of oscillation:	0.6 s^{-1}	0.6 s^{-1}
Number of cycles:	5,000	5,000
Ball diameter:	6 mm	6 mm
Ball material:	SS440C grade 25	SS440C grade 25
Lubricant:	Motor oil (Mobil Super, 10W-30)	Motor oil (Mobil Super, 10W-30)
Cleaning static partner:	IPA	IPA
Cleaning sample:	IPA	IPA
Atmosphere:	Air	Air
Relative Humidity:	45-48%	45-48%
Temperature:	~200-225F	~200-225F

Wear Track & Volume Loss

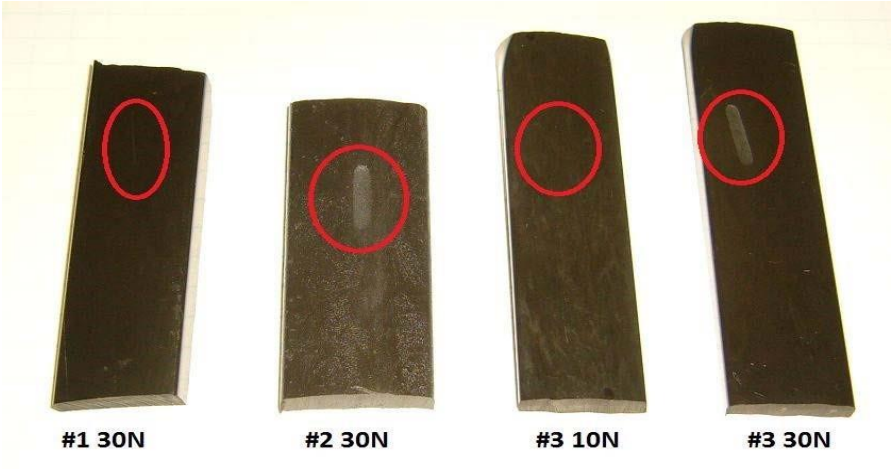
Lower is better.

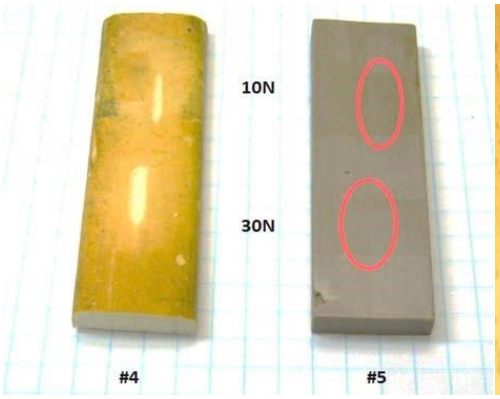
Specimen (Tested at 200-225F, Lubricated in Oil)	Disk Cross Section Wear Track [microns^2]	Disk Volume Loss* [mm^3]	Ball Wear Cap Diameter [microns]
#1 RFG (Glass/Mineral Filled)			
10N	NM	NM	**
30N	343 ± 106	0.00343	**
#2 TG PPS (Glass/Mineral Filled)			
10N	45,954 ± 7,656	0.45954	Abrasion**
30N	289,000 ± 41,000	2.89	Abrasion**
#3 RFG Impact Modified			
10N	276 ± 74	0.00276	**
30N	177,966 ± 15,257	1.78	Abrasion**
#4 AU (Amodel Unfilled)			
10N	109,862 ± 49,400	1.10	Abrasion**
30N	355,100 ± 57,000	3.55	Abrasion**
#5 PAEK GF40			
10N	NM*	NM*	**
30N	NM*	NM*	**
#6 AF GF30			
10N	50,981 ± 6,578	0.5081	**
30N Run 1 30N	93,118 ± 30,612	0.93118	**
Run 2	136,480 ± 12,765	1.36480	**
#7 KD 4320M Sucker Rod Wrench Flat	Not Tested for Wear	Not Tested for Wear	Not Tested for Wear
#8 Polyketone, Unfilled			
10N	3,782 ± 195	0.03782	**
30N	8,620 ± 390	0.08620	**
#9 Polyketone, 5% Glass Fiber Filled			
10N	664 ± 194	0.00664	**
30N	3,256 ± 390	0.03256	**
#10 Polyketone, 10% Glass Fiber Filled			
10N	908 ± 278	0.00908	**
30N	3,530 ± 243	0.03530	**
#11 Polyketone, 15% Glass Fiber Filled			
10N	820 ± 197	0.00820	**
30N	3,291 ± 448	0.03291	**
#12 Polyketone, 20% Glass Fiber Filled			
10N	not determined	not determined	**
30N	2,359 ± 228	0.02359	**
#13 Polyketone, 30% Glass Fiber Filled			
10N	669 ± 149	0.00669	**
30N	2,154 ± 510	0.02154	**

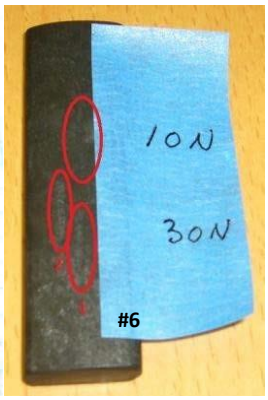
*: Values computed with the average cross section (disk/specimen).

**: No wear cap/no flat NM:
not measurable

NM*: visible wear, but not measurable due to surface roughness.

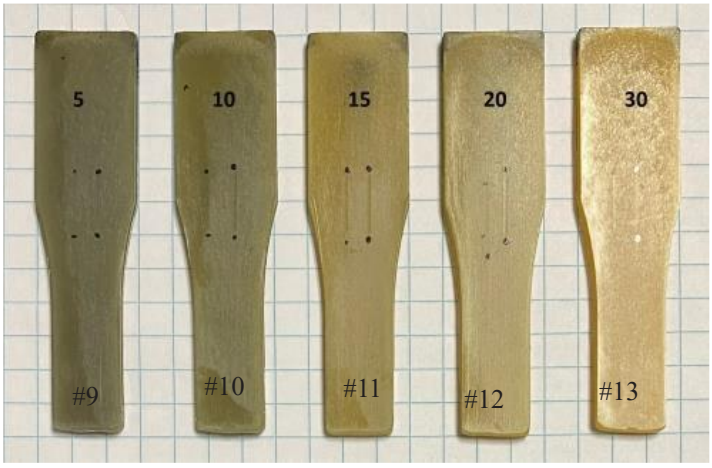

#1 30N
#2 30N
#3 10N
#3 30N


10N
30N
#4
#5


10N
30N
#6

10
30

#8


5
10
15
20
30
#9
#10
#11
#12
#13

Supplemental Information – Wear Factor and Wear Rate

Lower is better.

Specimen (Tested at 200-225F, Lubricated in Oil)	Disk Wear Factor [10^{-5} mm^3/Nm]	Disk Wear Rate [10^{-5} mm^3/m]
#1 RFG MP (Glass/Mineral Filled)		
10N	NM	NM
30N	0.11 ± 0.04	3.31 ± 1.20
#2 TG PPS (Glass/Mineral Filled)		
10N	45.86 ± 7.64	459.52 ± 76.55
30N	96.20 ± 13.60	2,891.39 ± 408.76
#3 RFG MP Impact Modified		
10N	0.28 ± 0.07	2.81 ± 0.70
30N	59.20 ± 5.08	1,779.32 ± 152.69
#4 AU (Amodel Unfilled)		
10N	109.65 ± 49.30	1,098.69 ± 493.99
30N	354.40 ± 56.90	10,651.85 ± 1,710.19
#5 PAEK GF40		
10N	NM*	NM*
30N	NM*	NM*
#6 AF GF30		
10N	50.9 ± 6.57	510.02 ± 65.83
30N Run 1	30.98 ± 10.19	931.17 ± 306.28
30N Run 2	45.41 ± 4.25	1,364.84 ± 127.74
#7 KD 4320M Sucker Rod Wrench Flat	Not Tested for Wear	Not Tested for Wear
#8 Polyketone, Unfilled		
10N	3,775 ± 195	37.82 ± 1.95
30N	2,868 ± 390	86.20 ± 3.90
#9 Polyketone, 5% Glass Fiber Filled		
10N	0.663 ± 0.194	6.64 ± 1.94
30N	1.084 ± 0.130	32.58 ± 3.91
#10 Polyketone, 10% Glass Fiber Filled		
10N	0.906 ± 0.278	9.08 ± 2.79
30N	1.175 ± 0.081	35.32 ± 2.44
#11 Polyketone, 15% Glass Fiber Filled		
10N	0.819 ± 0.197	8.21 ± 1.97
30N	1.095 ± 0.149	32.91 ± 4.48
#12 Polyketone, 20% Glass Fiber Filled		
10N	not determined	not determined
30N	0.785 ± 0.076	23.60 ± 2.28
#13 Polyketone, 30% Glass Fiber Filled		
10N	0.668 ± 0.149	6.69 ± 1.49
30N	0.717 ± 0.170	21.55 ± 5.11

Values computed with the average cross section (disk/specimen).
NM*: visible wear, but not measurable due to surface roughness.

Supplemental Information – Coefficient of Friction

Lower is better.

Specimen (Lubricated in Oil, Tested at 200-225F)	Average** μ
#1 RFG MP (Glass and Mineral Filled)	
10N	0.088 ± 0.021
30N	0.082 ± 0.022
#2 TG PPS (Glass and Mineral Filled)	
10N	0.067 ± 0.025
30N	0.071 ± 0.009
#3 RFG MP Impact Modified	
10N	0.087 ± 0.010
30N	0.083 ± 0.036
#4 AU (Amodel Unfilled)	
10N	0.076 ± 0.064
30N	0.073 ± 0.023
#5 PAEK GF40	
10N	0.063 ± 0.005
30N	0.055 ± 0.005
#6 AF GF30	
10N	0.103 ± 0.005
30N Run 1	0.114 ± 0.017
30N Run 2	0.085 ± 0.013
#7 KD 4320M Sucker Rod Wrench Flat	
10N	0.112 ± 0.005
30N	0.096 ± 0.006
#8 Polyketone, Unfilled	
10N	0.067 ± 0.010
30N	0.066 ± 0.004
#9 Polyketone, 5% Glass Fiber Filled	
10N	0.074 ± 0.008
30N	0.064 ± 0.005
#10 Polyketone, 10% Glass Fiber Filled	
10N	0.906 ± 0.278
30N	1.175 ± 0.081
#11 Polyketone, 15% Glass Fiber Filled	
10N	0.070 ± 0.009
30N	0.061 ± 0.006
#12 Polyketone, 20% Glass Fiber Filled	
10N	0.064 ± 0.014
30N	0.056 ± 0.010
#13 Polyketone, 30% Glass Fiber Filled	
10N	0.059 ± 0.010
30N	0.056 ± 0.009

**: two-way extraction

General Comments Pertaining to Wear & Friction Testing

This test method is designed to simulate the geometry and motions that are experienced in many types of rubbing components whose normal operation results in periodic reversals in the direction of relative sliding. The wear resulting from this mode of movement may differ from that experienced by the same materials sliding continuously in only one direction (unidirectional sliding) even for comparable durations of contact.[3]

Owing to the nature of this type of test, the wear scar on the ball specimen may not always be circular or flat.[3]

The repeatability of tests on the same material will depend upon material homogeneity, machine and material interaction[1,2].

It is important to keep in mind that friction is a system property. Appropriate caution must be used when comparing or using data from different sources and systems. Friction coefficients of material couples obtained on one type of test apparatus may be significantly different from coefficients of the same material couples tested on a different apparatus[2].

The precision of wear determinations is dependent on the wear characteristics of the material under the imposed testing conditions. Some materials wear evenly so as to produce clearly defined wear scars, and wear dimensions can be measured with a higher degree of precision than for certain other materials which wear in an uneven manner and whose wear scars cannot be delineated as clearly.[3]

Unlike material combinations may wear at different rates depending on which material is the ball specimen and which is the flat specimen. The ball specimen experiences nominally constant contact, whereas the flat specimen surface experiences a changing state of stress as the slider passes and may wear by a different set of mechanisms. It should therefore not be assumed that the same relative wear volumes would be obtained if materials for ball and flat specimens were reversed.[3]

The amount of wear in any system will, in general, depend upon the number of system factors such as the applied load, machine characteristics, sliding speed, sliding distance, the environment, and the material properties. The value of any wear test method lies in predicting the relative ranking of material combinations. Since the pin-on-disk test method does not attempt to duplicate all the conditions that may be experienced in service (for example: lubrication, load, pressure, contact geometry, removal of wear debris, and presence or corrosive environment), there is no assurance that the test will predict the wear rate of a given material under conditions differing from those in the test.[1]

Reference 1: ASTM G99 Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus
Reference 2: ASTM G115 Standard Guide for Measuring and Reporting Friction Coefficient
Reference 3: ASTM G133 Standard Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear

END OF REPORT