MiSUMi®
Configured to Save Time™

RAINBOW-DIAMOND LIKE CARBON (R-DLC) LOCATING PIN

COMPARISON STUDY

Developed by: The MISUMI Automotive Business Development Team
03.17.2020

CONTENTS

Introduction

Material surfaces can wear over time due to the application environment especially applications due to friction between the fixture component and workpiece. To mitigate this, specific coatings are used to add life to a component and decrease downtime due to replacement. For locating pins, many applications will require a surface to surface contact of steel and aluminum workpieces therefore it is important for the pin to have a wear resistant coating.

First, let's review the different material types of locating pins. M2 High-Speed Steel (M2) is tungsten-molybdenum high-speed steel with a well-balanced composition suitable for a wide variety of applications. Worldwide, the M2 type is by far the most popular high-speed steel having replaced T1 high speed in most applications because of its superior properties and relative economy. They belong to the Fe–C–X multi-component alloy system where X represents chromium, tungsten, molybdenum, vanadium, or cobalt.

Next, there is 52100 steel which is a type of low alloy steel. It consists of the elements carbon, chromium, iron, manganese, silicon, phosphorus, and Sulphur, with high levels of carbon and chromium. This grade of steel is corrosion-resistant, has excellent hardenability and good machinability. It is mainly used commercially to make steel bearings.

6061-T6 aluminum is 6061 aluminum in the T6 temper. To achieve this temper, the metal is a solution heat-treated and artificially aged until it meets standard mechanical property requirements one of the most common alloys of aluminum for general-purpose use.

In this study, MISUMI tested the unique coating called Rainbow Diamond-like Carbon or R-DLC for short. Diamond-like carbon (DLC) is a class of amorphous carbon material that displays some of the typical properties of diamond. DLC is usually applied as coatings to other materials.

This white paper is split up into the tests that were performed:

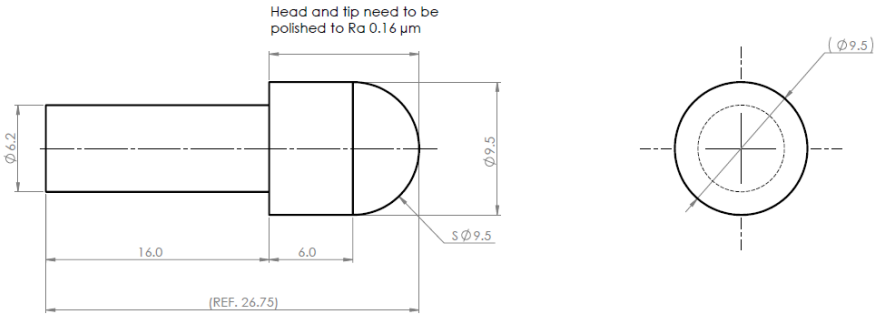
- Hardness (HIT) and Indentation Modulus (EIT)
- Coefficient of Friction and Wear Rate
- Statistical Tests for Each
- M2 Steel Coating Independent Wear Testing

Sample Identification and Specifications

Test Materials

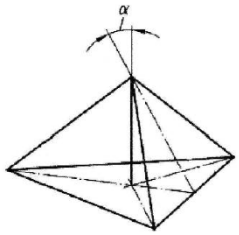
Pin Material	Coating	Coating thickness	Steel 52100	Aluminum Al6061-T6
M2	#1 plain	0 µm	1	1
	#1A plain	0 µm	1	1
	#2 MISUMI R-DLC	0.5 µm	1	1
	#2A MISUMI R-DLC	0.5 µm	1	1
	#3 Company A	0.6 µm	1	1
	#3A Company A	0.6 µm	1	1

Sample Pin Drawing



Hardness (HIT) and Indentation Modulus (EIT) Testing

For locating pins, it is important for them to have high surface hardness due to constant the surface to surface contact. Therefore, testing the hardness is key for these specimens. Testing was performed in accordance with ASTM E2546 Nano Hardness Tester “NHT” from CSM Instruments, S/N 6-135 with module S/N 080820; software “Indentation” version 3.81.05.



Indenter Geometry (three sided pyramid, modified Berkovich, α = 65.3 ± 0.3)

Berkovich tip is a type of nanoindenter tip used for testing the indentation hardness of a material.

Results

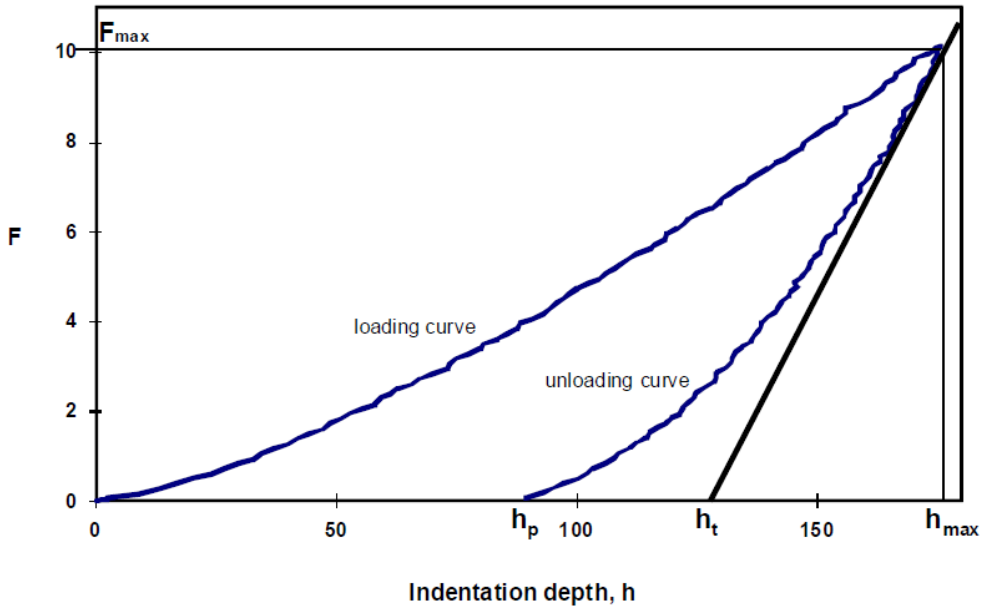
The measured values of indentation hardness (HIT), indentation modulus (EIT) and maximum indenter displacement into the sample (h max) are tabulated below with their averages and standard deviations. Table 1 presents a summary of the results.

Test Parameters:
Maximum displacement : 10 µm
Displacement resolution : 0.3 nm
Maximum force : 300 mN
Force resolution : 5 µN

Overall, it took more force to place an indent on the MISUMI R-DLC pins compared to the other sample types.

Table 1

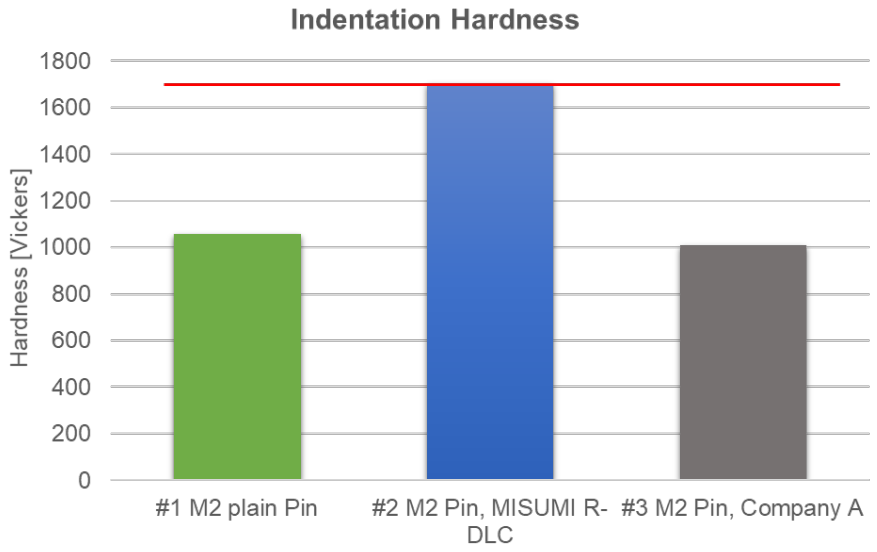
Sample Type	H IT [Vickers]	H IT [MPa]	E IT [GPa]
#1 M2 plain pin	1180.4 ± 174.0	12746 ± 1879	238.75 ± 24.51
#1A M2 plain pin	930.1 ± 164.2	10043 ± 1774	226.24 ± 20.04
#2 M2 Pin, MISUMI R-DLC	1698.4 ± 394.4	18339 ± 4259	259.20 ± 34.61
#2A M2 Pin, MISUMI R-DLC	1712.1 ± 318.1	18487 ± 3435	273.18 ± 37.83
#3 M2 Pin, Company A	1030.5 ± 337.3	11126 ± 3642	248.46 ± 60.82
#3A M2 Pin, Company A	983.1 ± 242.1	10615 ± 2614	228.99 ± 34.43

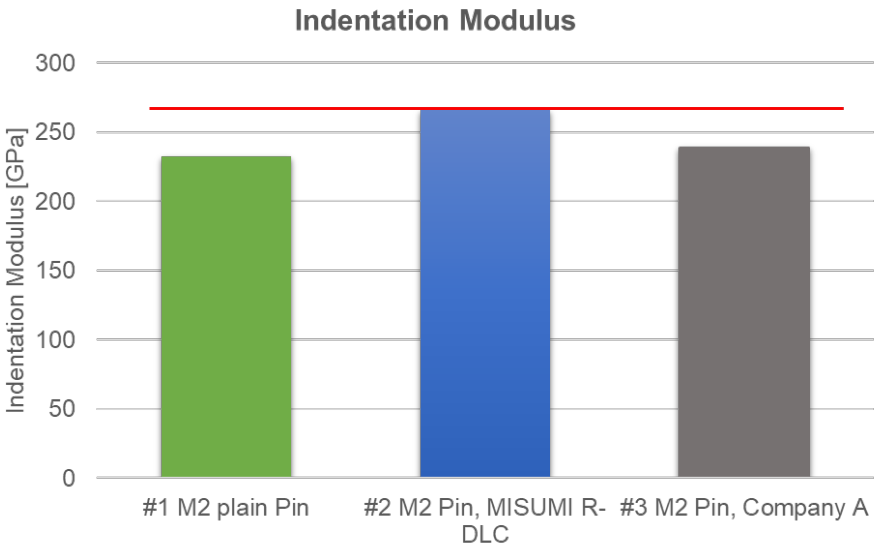


HIT and EIT Graphic Results

Indentation Hardness (HIT) [Vickers]	
#1 M2 plain Pin	1055.25
#2 M2 Pin, MISUMI R-DLC	1705.25
#3 M2 Pin, Company A	1006.80

Indentation Modulus (EIT) [GPa]	
#1 M2 plain Pin	232.49
#2 M2 Pin, MISUMI R-DLC	266.19
#3 M2 Pin, Company A	238.72





HIT and EIT Statistical Results

A T-test is used to determine the significant difference between the averages of two different data sets.

T- test was done between:

- Group 1 M2 Pin, MISUMI R-DLC
- Group 2 M2 Pin, Company A

Test Conditions:
NULL HYPOTHESIS: group1 = group 2

ALTERNATIVE: GROUP 1 > GROUP 2

Confidence Level 95%
MOE- 5%
2-tailed test

Test Statistics

	Hardness
Mann-Whitney U	9.000
Wilcoxon W	75.000
Z	-3.898
Asymp. Sig. (2-tailed)	0.00010
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

a. Grouping Variable: GROUP

b. Not corrected for ties.

Test Statistics

	Indentation Modulus
Mann-Whitney U	61.000
Wilcoxon W	127.000
Z	-1.332
Asymp. Sig. (2-tailed)	0.183
Exact Sig. [2*(1-tailed Sig.)]	.195[b]

a. Grouping Variable: GROUP

b. Not corrected for ties.

T-test proved:

- MISUMI R-DLC is harder than Company A
- MISUMI R-DLC and Company A have equal performance on the Indention Modulus testing

Coefficient of Friction and Wear Rate Testing

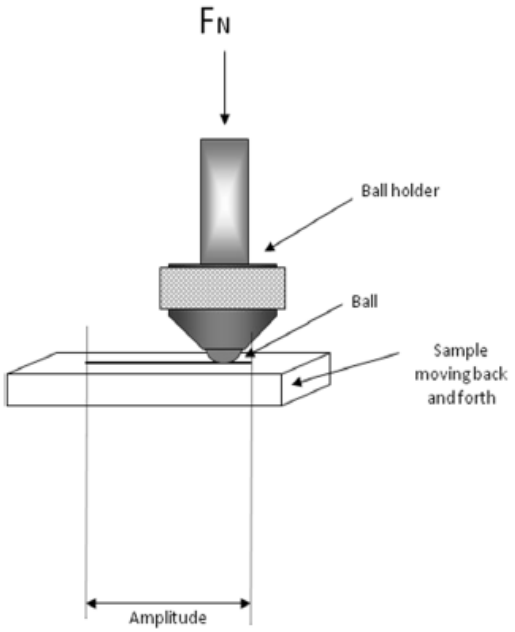
Test was performed with a Pin-on-Disk “Tribometer” from CSM Instruments, S/N 18-281 with “linear module” S/N 1-120; software “InstrumX” version 2.7. Profiles were processed and analyzed with the surface analysis software “Mountains” from Digital Surf.

ASTM G133-05(2016) Standard Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear 1.1. This test method covers laboratory procedures for determining the sliding wear of ceramics, metals, and other candidate wear-resistant materials using a linear, reciprocating ball-on-flat plane geometry.

Testing Standard: ASTM G133 Procedure A, except for the following:
The wear factor/rate profiles extracted were taken in an area at the center of the stroke.

Specimens

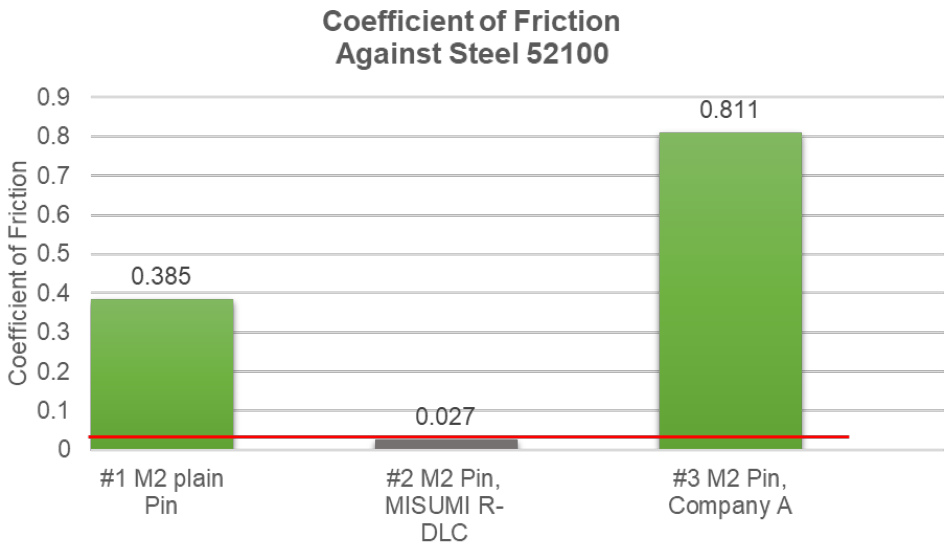
- M2 uncoated pins
- M2 R-DLC pins
- M2 Company A pins
- Tested against steel 52100 and Al6061-T6

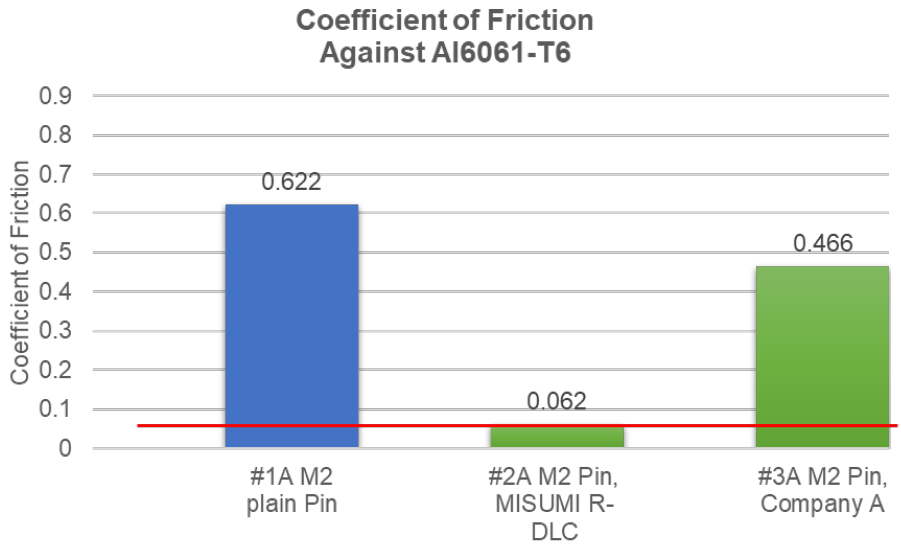


CoF Graphic Results

Coefficient of Friction (Average μ) Against Steel 52100	
#1 M2 plain Pin	0.385±0.12
#2 M2 Pin, MISUMI R-DLC	0.027±0.02
#3 M2 Pin, Company A	0.811±0.13

Coefficient of Friction (Average μ) Against Al6061-T6	
#1A M2 plain Pin	0.622±0.21
#2A M2 Pin, MISUMI R-DLC	0.062±0.04
#3A M2 Pin, Company A	0.466±0.16

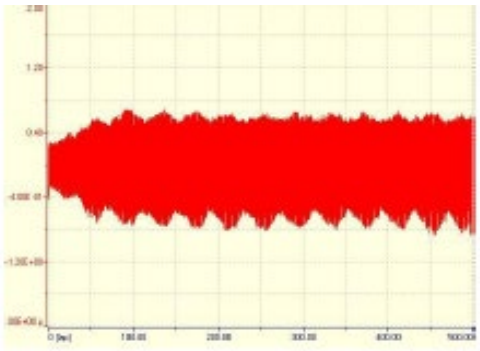




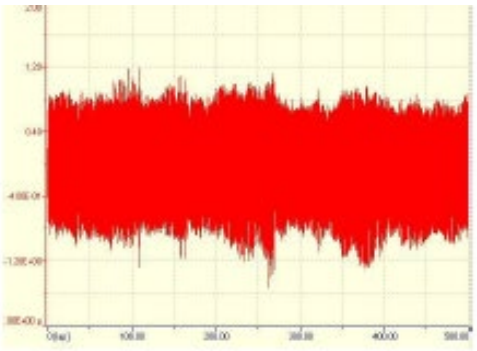
CoF Instantaneous Graphic Results

Below are the results of Coefficient of friction testing during the entire duration of the test. The software extracts the friction value as the pin travels at the center point of the stroke. There is a smoother transition for MISUMI R-DLC when moving back and forth along the test sample surface as compared to Company A coating.

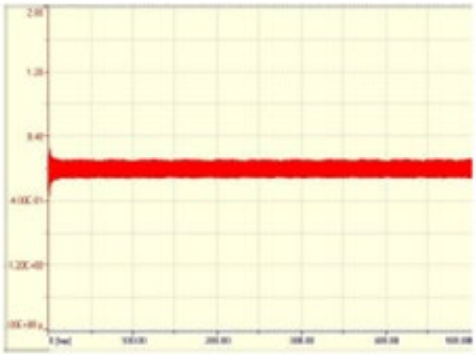
#1 Plain



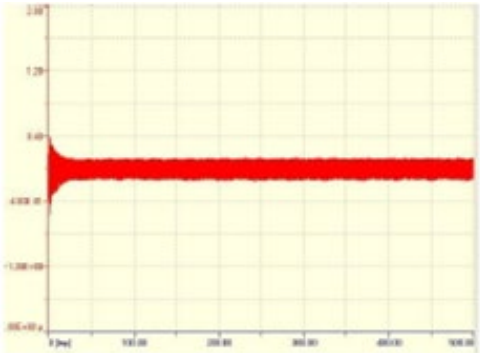
#1A Plain



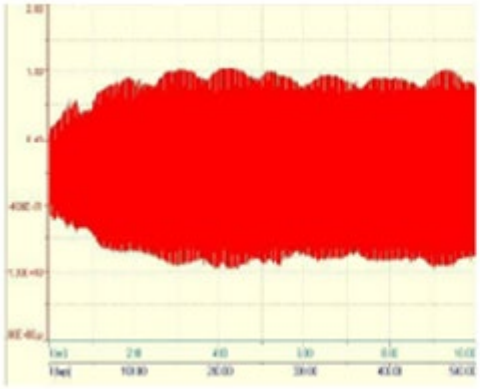
#2 MISUMI R-DLC



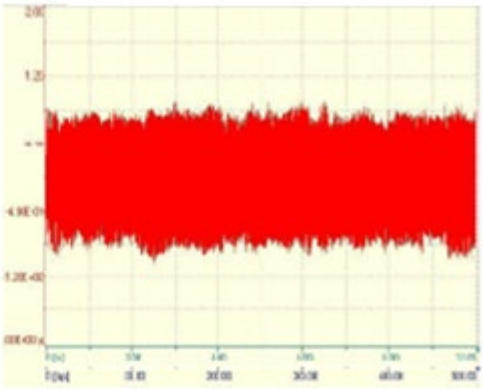
#2A MISUMI R-DLC



#3 Company A



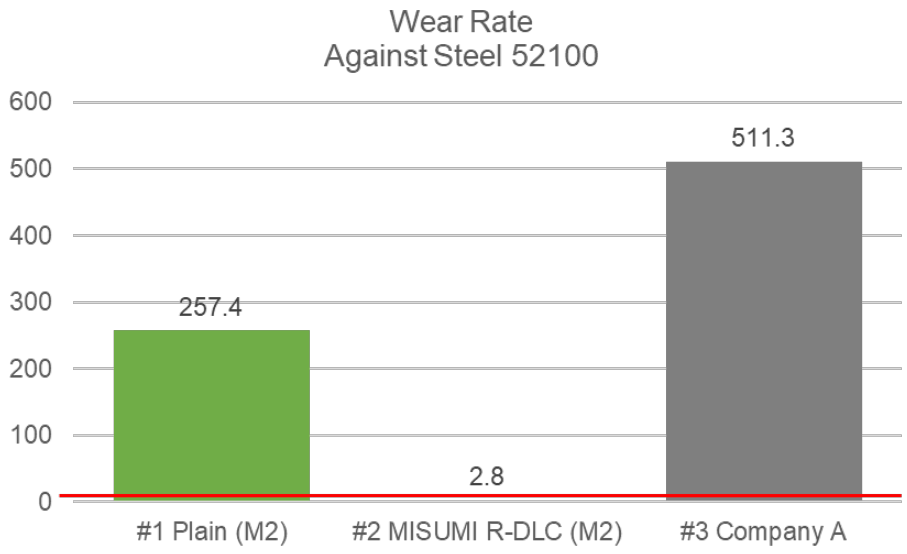
#3A Company A

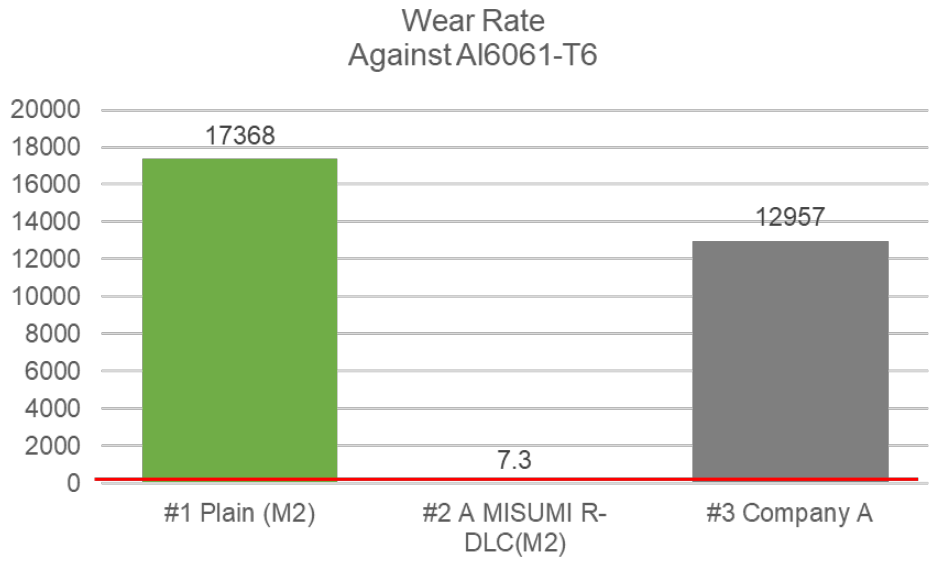


Wear Rate Graphic Results

Wear Rate Against Steel 52100	
#1 M2 plain Pin	257.4±5.3
#2 M2 Pin, MISUMI R-DLC	2.8±0.5
#3 M2 Pin, Company A	511.3±17.8

Wear Rate Against Steel 52100	
#1 M2 plain Pin	257.4±5.3
#2 M2 Pin, MISUMI R-DLC	2.8±0.5
#3 M2 Pin, Company A	511.3±17.8





Wear Rate Statistical Results

T-test was done between 2 groups of data:

- Group 1 M2 Pin, MISUMI R-DLC
- Group 2 M2 Pin, Company A

Test Conditions:
NULL HYPOTHESIS: group1 = group 2
ALTERNATIVE: GROUP 1 < GROUP 2
Confidence Level 95%
MOE- 5%
One-tailed test

Group Statistics

GROUP		N	Mean	Std. Deviation	Std. Error Mean
Steel 52100	MISUMI	10002	0.0712	0.0286	0.00028
	Company A	9985	0.7825	0.2111	0.0021129660

Group Statistics

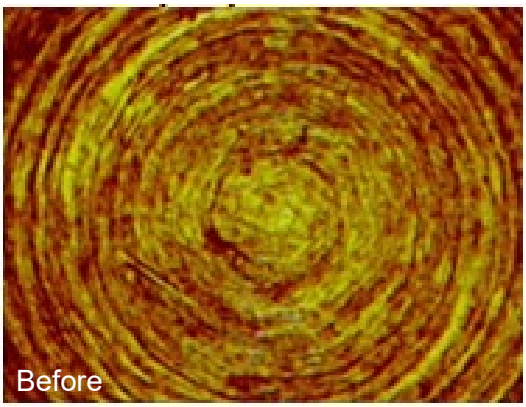
GROUP		N	Mean	Std. Deviation	Std. Error Mean
A66061	MISUMI	10004	0.087470	0.0376	0.000376
	Company A	9980	0.547220	0.1772	0.001775

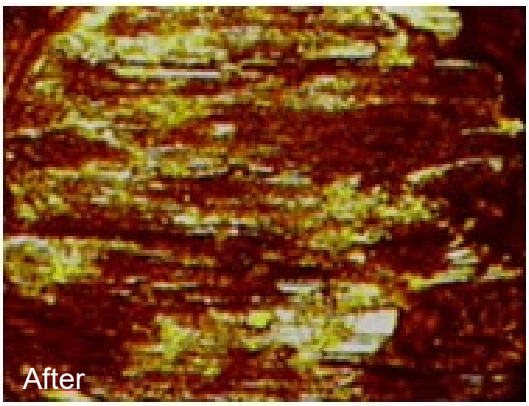
T-Test Proved:

- MISUMI R-DLC has lower Coefficient of Friction than Company A on all materials

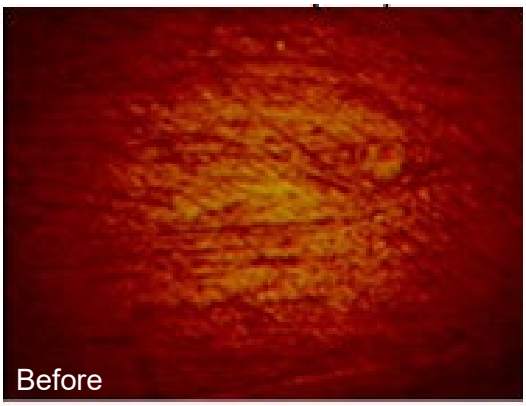
Wear Rate Photographic Results - Against Steel 52100

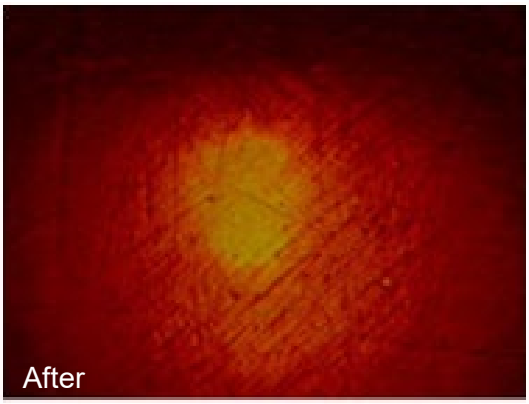
#1 Plain



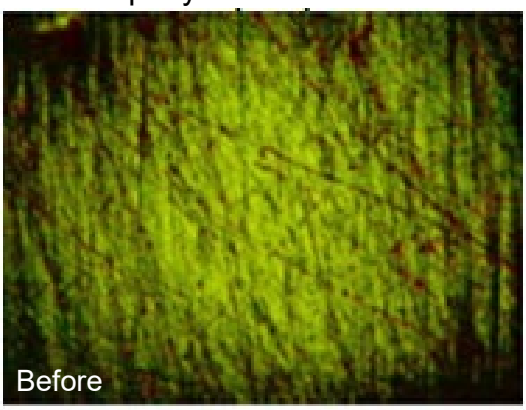


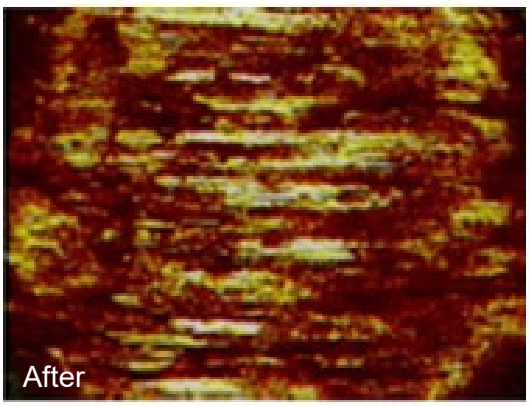
#2 MISUMI R-DLC





#3 Company A

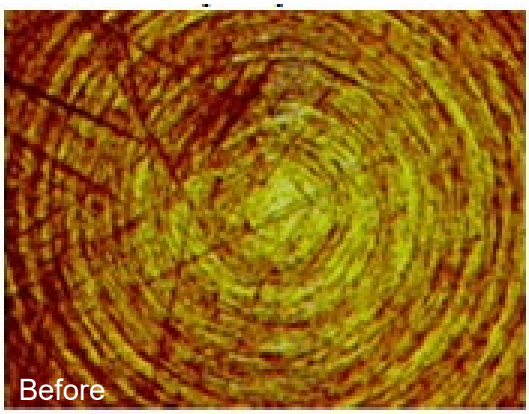


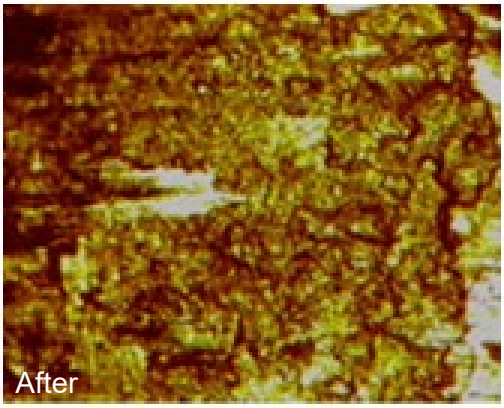


Before and after images of wear rate testing magnified 50 times. The after pictures of sample #1 and sample #3 show material buildup on the tested pin, there is material transfer/debris and other slight marking/polishing.

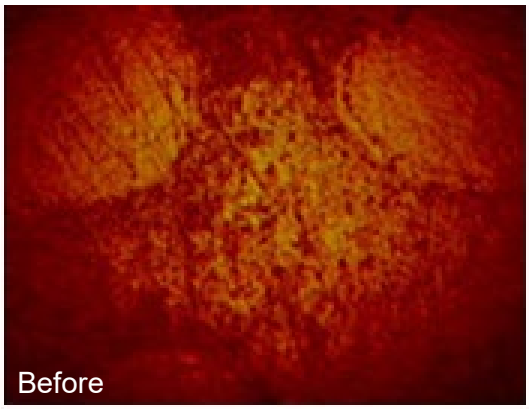
Wear Rate Photographic Results - Against Aluminum Al6061-T6

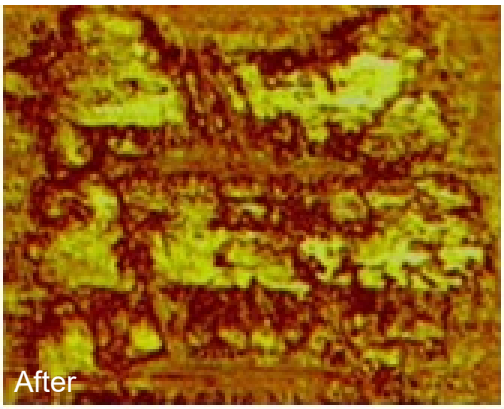
#1A Plain



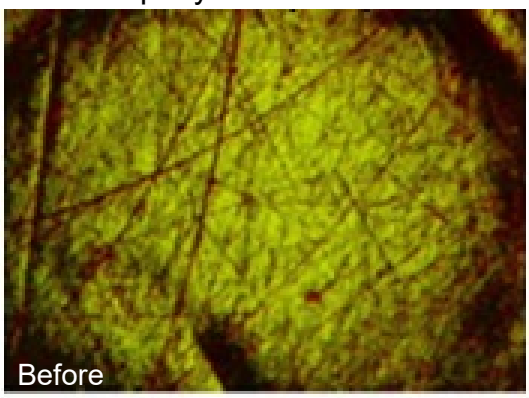


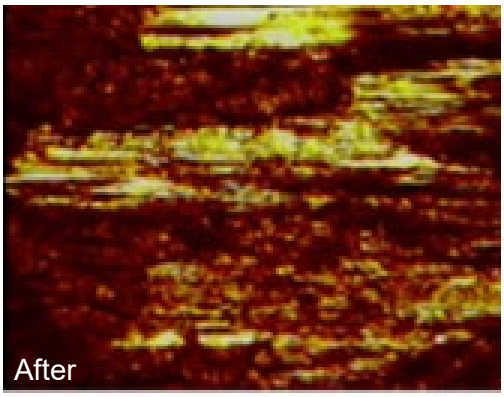
#2A MISUMI R-DLC





#3A Company A





Before and after images of wear rate testing magnified 50 times. The after pictures of sample #1 and sample #3 show material buildup on the tested pin, there is material transfer/debris and other slight marking/polishing.

M2 Steel Coating Independent Wear Test

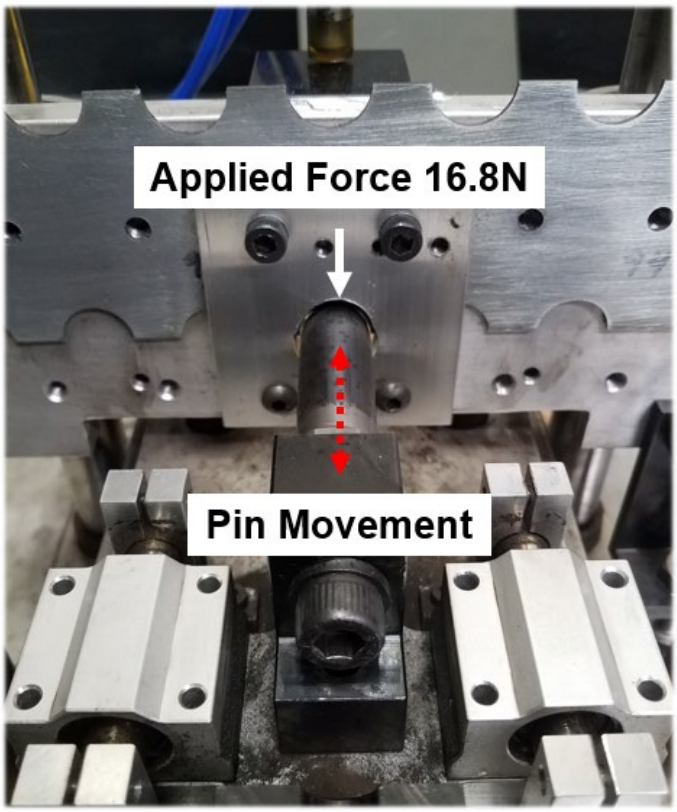
The MISUMI Automotive Business team performed in-house, independent wear testing to compare 3 different coatings available in the market. Pins were observed daily at regular intervals for any visible signs of wear. At first sign of coating/wear damage results were collected and testing was concluded when vibration and noise occurred.

Test Specimens:

Type: APS195M standard NAAMS pin
Sheet Metal Material: High Strength Steel
Coatings:
1) MISUMI R-DLC
2) Competitor 1 Lasercut 964
3) Competitor 2 CeraTough™-0710

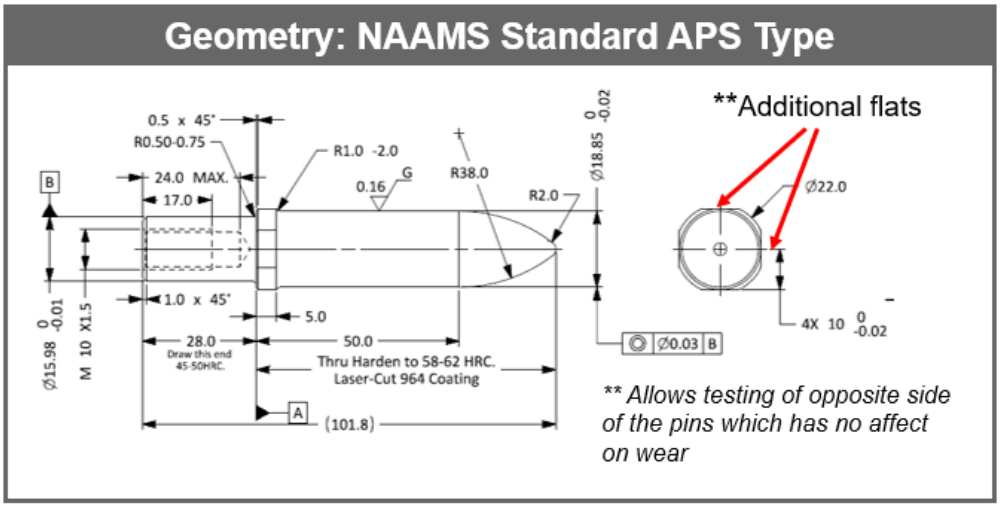
Test Conditions:

All specimens were exposed to the same test conditions.
Test Period: 2 months (10/2019 – 12/2019)
Cycle Rate: 46 cycles/minute
Applied Force: 16.8 N Y-Axis



Test Samples:

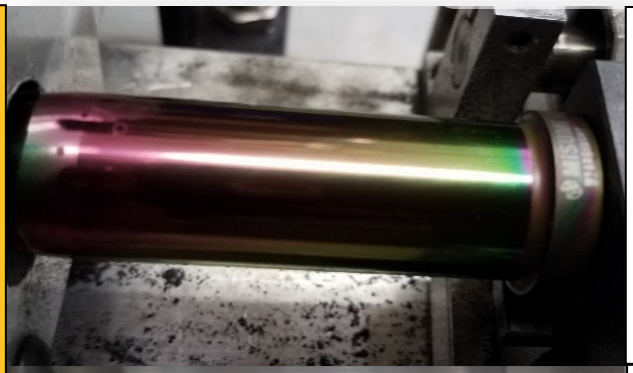
Brand	Coating Type	Coating Thickness	Hardness
MISUMI	R-DLC	0.5 - 1 µm	6,000 - 7,000 HV
Competitor 1	Lasercut 964	0.5 - 1.5 µm	4,800 HV
Competitor 2	CeraTough™-0710	0.5 µm	5,000 HV

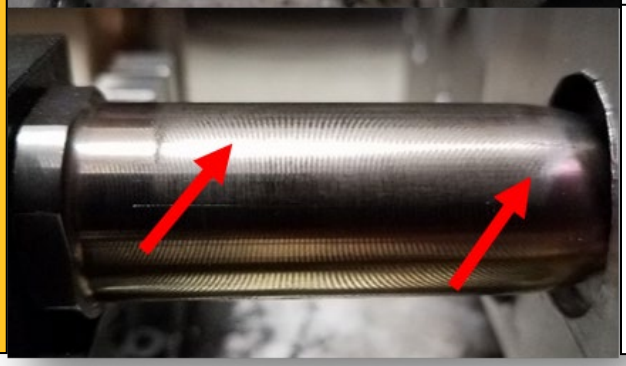


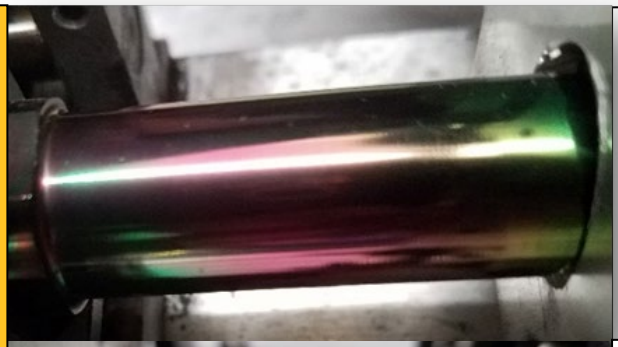
The tolerances of each sample were examined before testing for verification. Below are the results of each measurement.

Brand	Head Outer Diameter	Shank Outer Diameter	Surface Finish	In Tolerance
MISUMI	ø18.843mm	ø15.976mm	0.23 µm – Grinding finish	✓
Competitor 1 Lasercut 964	ø18.852mm	ø15.994mm	1.2 µm – No Grinding finish	✗
Competitor 2 CeraTough™-0710	ø18.835mm	ø15.97mm	0.27 µm – No Grinding finish	✓

Test Results:

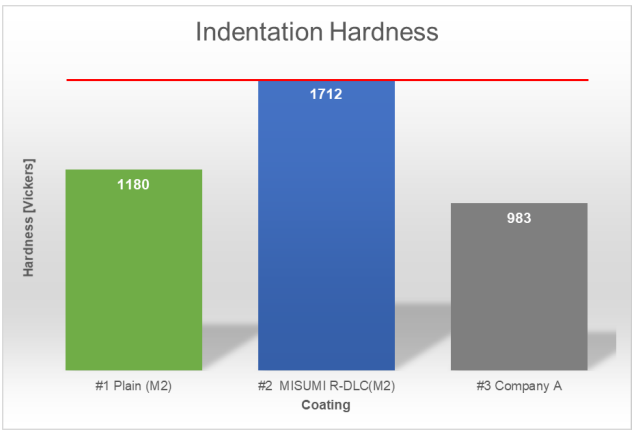
MISUMI R-DLC		**1k** cycles. No wear on the coating.
		**143k** cycles. Minimal wear on the coating.
		**250,000 cycles** Testing concluded.

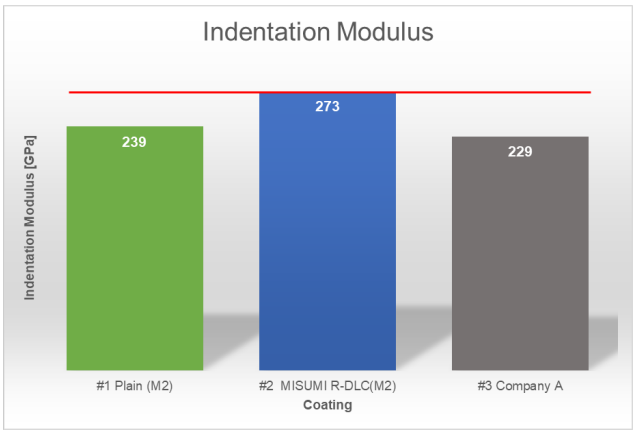
Lasercut 964		**500** cycles. Visual wear from the head.
		**6k** cycles. Coating is removed from head and testing completed.

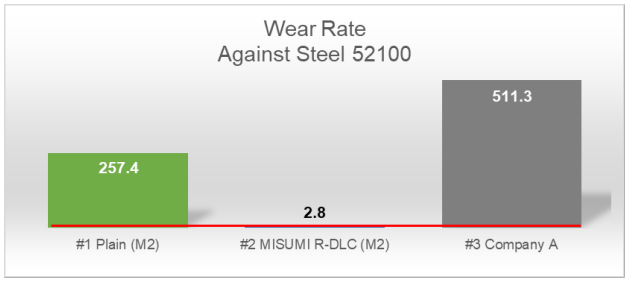
Cera-Tough™ 0710	
	**2k** cycles. No visual wear on the head.
	**4k** cycles. Visual wear on the head.
	**22,000** cycles. Testing completed.

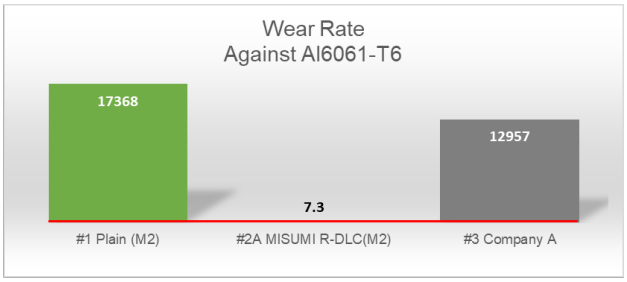
Conclusion

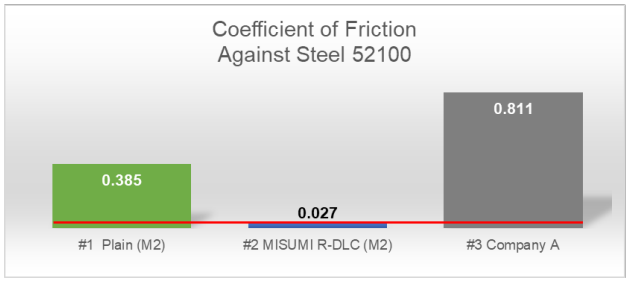
- MISUMI R-DLC coating has a higher hardness (HIT) than Company A.
- MISUMI R-DLC coating has equal performance on indention modulus (EIT).
- MISUMI R-DLC coating has a lower Coefficient of Friction than Company A on Steel 52100 and AL6061-T6 materials.
- MISUMI R-DLC shows a lower wear rate than Company A on Steel 52100 and AL6061-T6 materials.
- MISUMI R-DLC pin was removed at 250,000 cycles vs. Competitor 1 & 2 at 6,000 & 22,000 Cycles. Therefore, the MISUMI R-DLC Pin has superior wear performance.

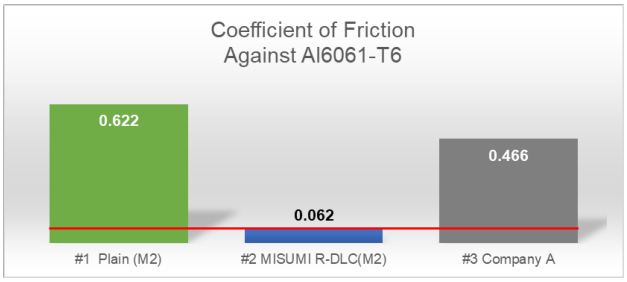

Indentation Hardness
Hardness [Vickers]
1180
1712
983
#1 Plain (M2)
#2 MISUMI R-DLC(M2)
#3 Company A
Coating

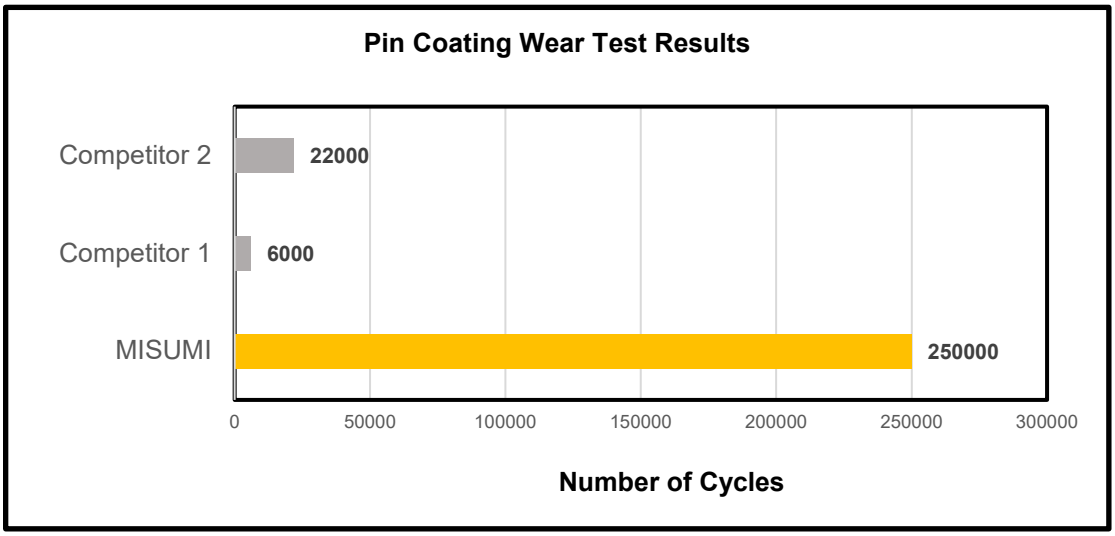

Indentation Modulus
Indentation Modulus [GPa]
239
273
229
#1 Plain (M2)
#2 MISUMI R-DLC(M2)
#3 Company A
Coating


Wear Rate
Against Steel 52100
257.4
2.8
511.3
#1 Plain (M2)
#2 MISUMI R-DLC (M2)
#3 Company A


Wear Rate
Against Al6061-T6
17368
7.3
12957
#1 Plain (M2)
#2A MISUMI R-DLC(M2)
#3 Company A


Coefficient of Friction
Against Steel 52100
0.385
0.027
0.811
#1 Plain (M2)
#2 MISUMI R-DLC (M2)
#3 Company A


Coefficient of Friction
Against Al6061-T6
0.622
0.062
0.466
#1 Plain (M2)
#2 MISUMI R-DLC(M2)
#3 Company A


Pin Coating Wear Test Results
Competitor 2
22000
Competitor 1
6000
MISUMI
250000
0
50000
100000
150000
200000
250000
300000
Number of Cycles

THANK YOU!
For more information, contact:
Engineering Team: engineering@misumiusa.com