Dr J. Stallard
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Test results for Bewise Inc.

1. Introduction

This report provides a brief introduction to the test equipment used for testing these samples. Information on the Pin-on-Disc tester is also provided which is used to measure sliding wear and friction.

2. Test Equipment

2.1 Ball Crater

The TEER-BC-I is a device that produces a crater. Ball Cratering is a simple method of producing a taper section to determine the coating thickness without the need to fracture the sample, the device is shown in Figure 1

Figure 1: The Ball Crater device

The method allows the different layers of the coating to be visible under an optical microscope giving additional information such as interface sharpness or layer thickness. A schematic representation of the crater and the basic equation for the determination of the coating thickness is shown below in Figure 2 and Equation 1.

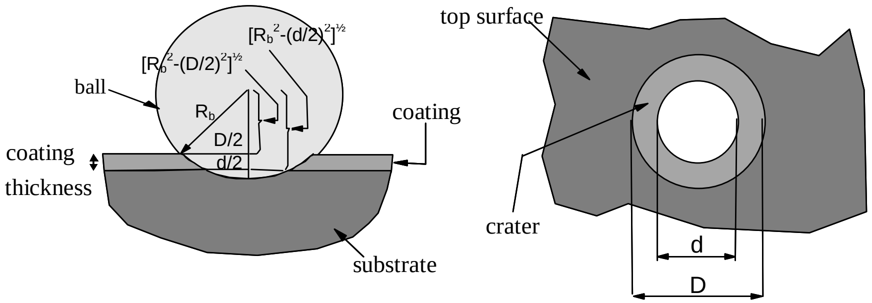


Figure 2: A schematic diagram of the crater and coating thickness determination

$$FilmThickness = \sqrt{R_b^2 - \left(\frac{d}{2}\right)^2} - \sqrt{R_b^2 - \left(\frac{D}{2}\right)^2}$$

Equation 1

The specifications for this piece of equipment are as follows:

- Ball: AISI 52100 Grade 15 chromium steel 30 mm diameter
- Polishing Agent: Diamond Paste Grade G3400 (1/4 μm grain size)

An optical microscope with a magnification of x50 and x100 is used to observe and analyse the resulting craters.

2.2 The ST3001 Tribo tester

Figure 3: The ST3001 Tribo tester

2.2.1 Wear testing

Wear testing is performed on a coated sample to measure the friction coefficient and acoustic emission of the coating at various loads in various environments, and the rate at which a coating wears away. The test can be performed with varying table speed, load and wear track length.

The friction force is recorded and displayed during the wear test. The programme includes the facility that the test stops automatically when the coating has failed (determined by a rise in friction, or acoustic emission, to a previously defined value), giving the number of cycles to failure.

2.2.2 Standard Scratch Adhesion Test

Scratch adhesion testing is performed on a coated sample to measure the critical load at which a coating shows signs of failure. The test can be performed with varying table speed, load rate, initial load and final load. The friction force and acoustic emission is recorded and displayed during the scratch test. The computer programme includes facilities so that the first derivative of the friction can be plotted to provide a clear indication of the load at which total coating failure occurs.

2.3 Pin on Disc

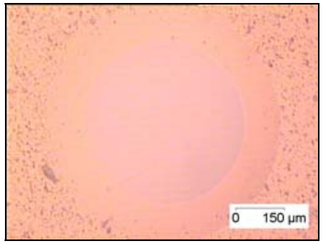
Figure 4: Teer Pin-on-Disc Wear Tester

The Teer Pin-On-Disc wear tester uses a low speed-high torque drive motor to rotate a flat sample under a loaded wear pin. The wear pin creates a circular wear track on the sample by offsetting the pin relative to the sample's centre of rotation and then rotating the sample. The sliding motion of the sample under the wear pin provides a frictional force which is a property of the film and is proportional to the load applied. Frictional force is detected by the load cell and recorded by the computer. Examination of the resulting plot of friction versus time can give an indication of the friction characteristics and endurance of a particular coating. The load can be varied by adjusting the amount of dead weight hung at the end of the loading beam, the mechanical advantage of the loading beam is x2. A ball crater applied to the wear track can be used to determine the depth of coating removed during the wear test period. By knowing the wear volume, load applied and sliding distance the Specific Wear Rate (units $m^3\ N^{-1}\ m^{-1}$) of the coating can be calculated. Figure 4 shows the PoD tester currently used for the routine testing of coatings.

3. Results on Coatings

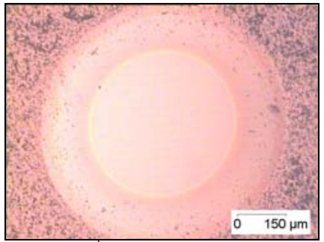
3.1 Coating thickness (µm) derived by Ball crater technique

TiN



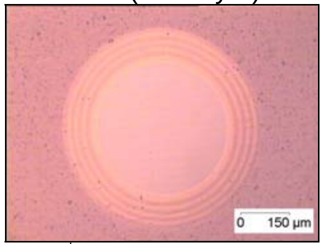
2.5µm

TiCN



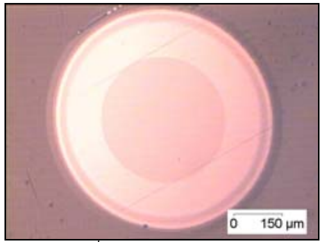
1st layer 2.3µm
2nd layer 1.1µm
Total 3.4µm

TiCN (multilayer)



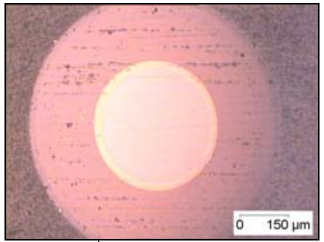
1st multilayer 0.4µm
2nd multilayer 0.3µm
Total 1.9µm

TiBCr



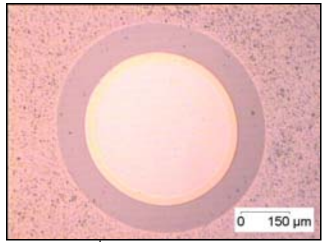
1st layer 2.5µm
2nd layer 0.8µm
Total 3.3µm

AlTiN



1st layer 0.4µm
2nd layer 3.9µm
Total 4.3µm

AlTiN + PLC



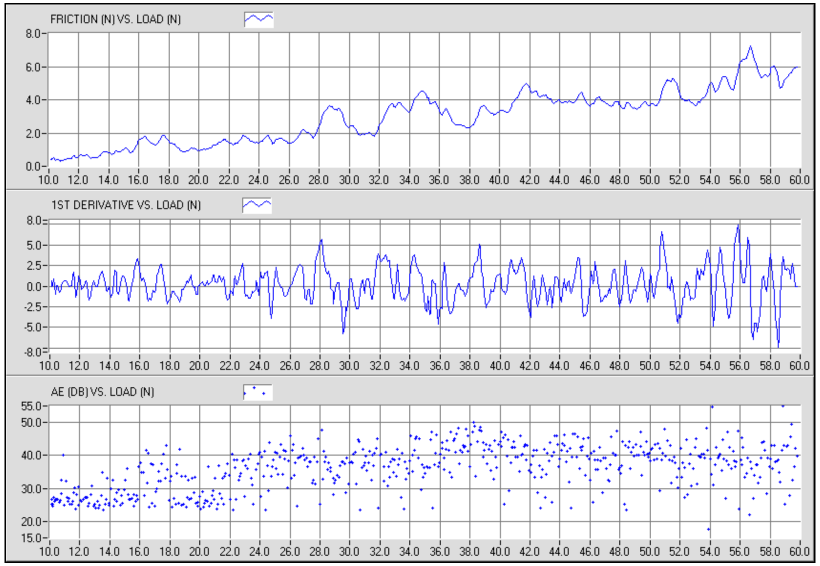
1st layer 0.4µm
2nd layer 1.7µm
Total 2.1µm

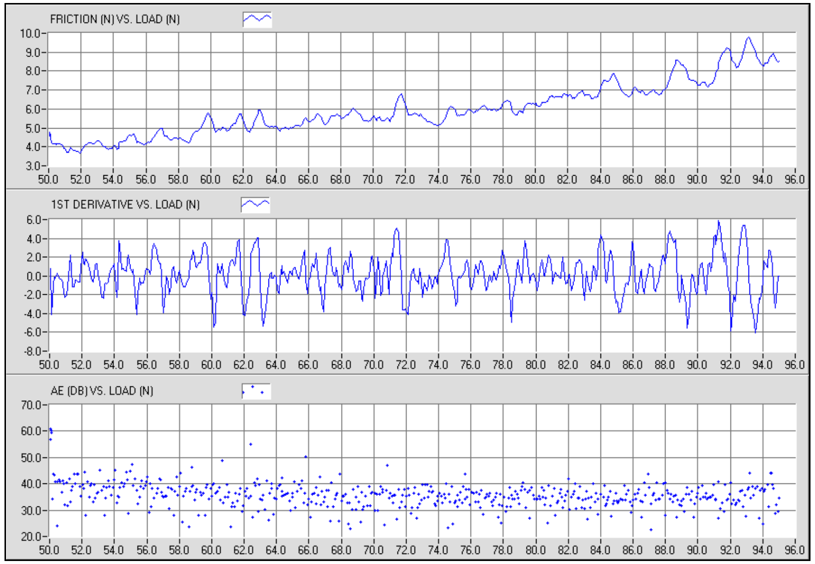
3.2 Scratch test

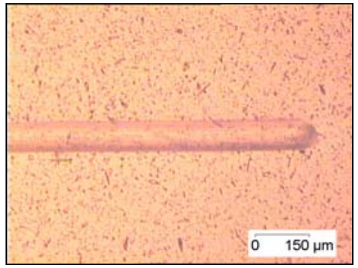
Rockwell diamond indenter (0.2mm tip radius), 5 to 60N load, 10mm/min. linear velocity, 100N/min. load rate. Scratch tests performed from left to right of sample.

TiN - 10N to 60N load

TiN – 50 to 96N load

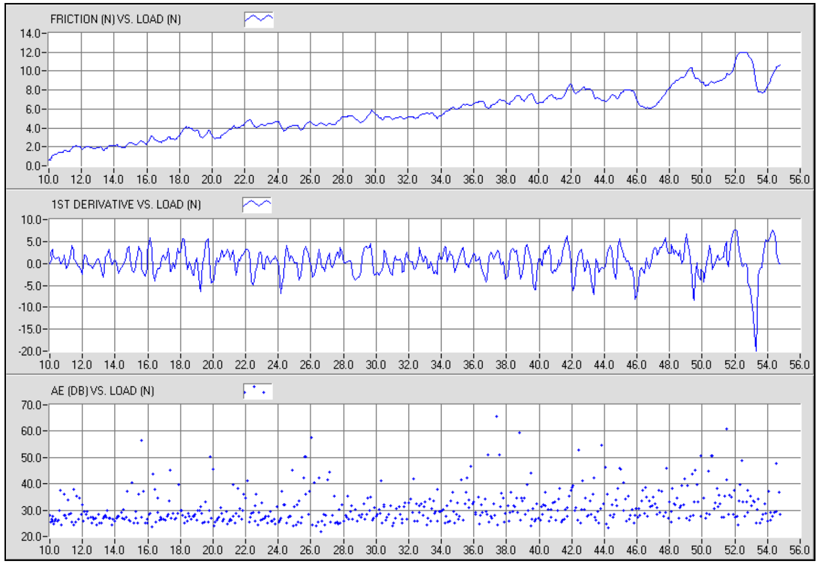


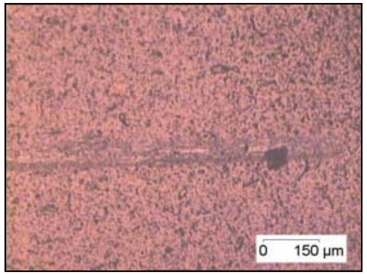




Total failure >96N

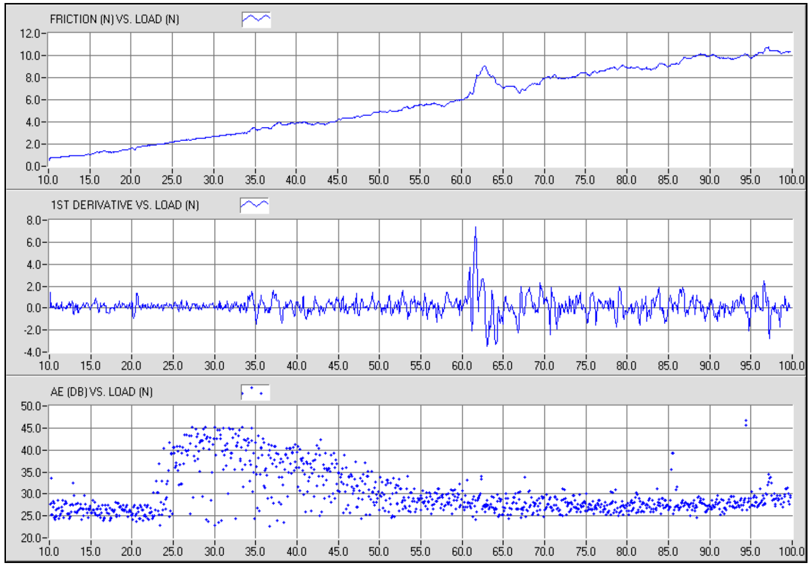
TiCN – 10N to 56N

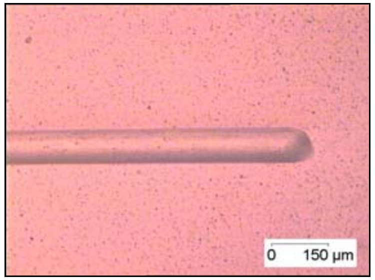




Initial failure 48N
Total failure >56N

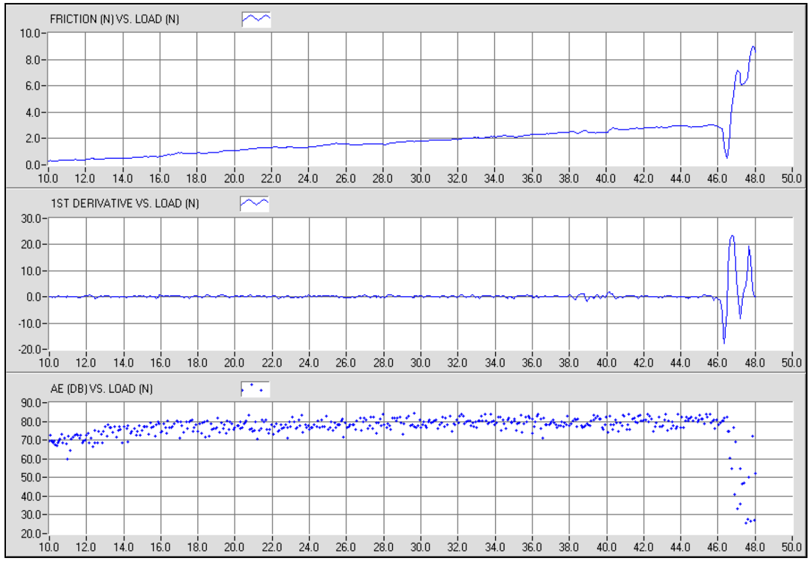
TiCN (multilayer) – 10N to 100N

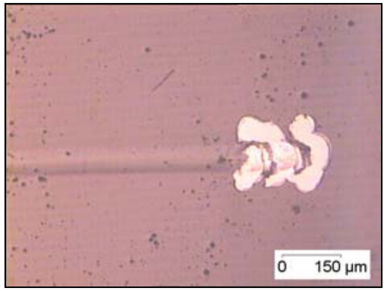




Total failure >100N

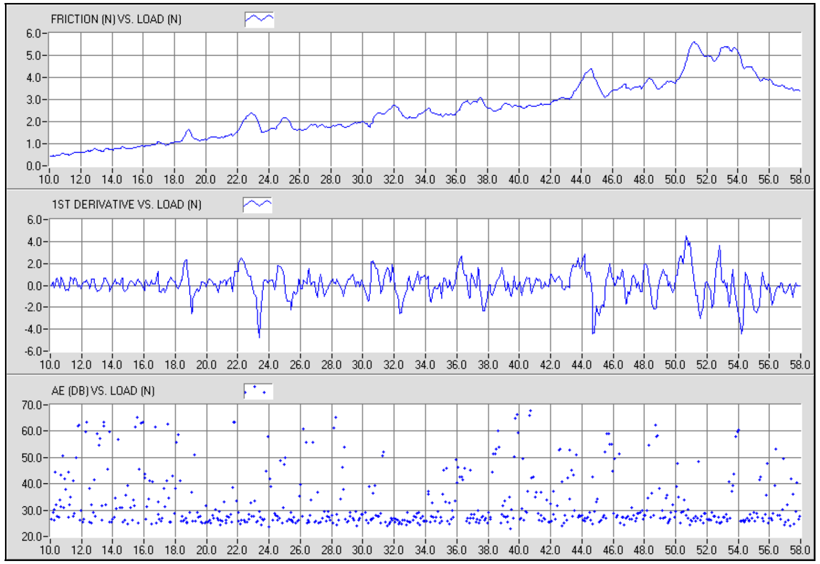
TiBCr – 10N to 48N



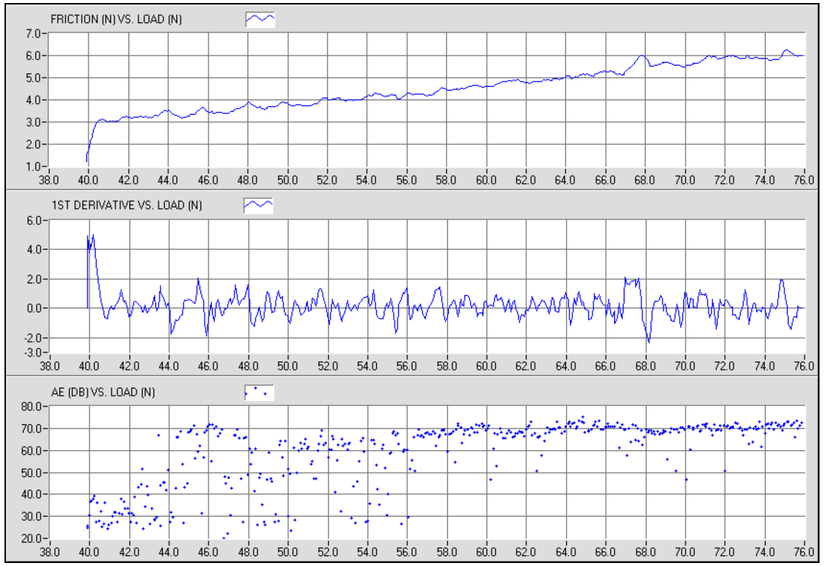


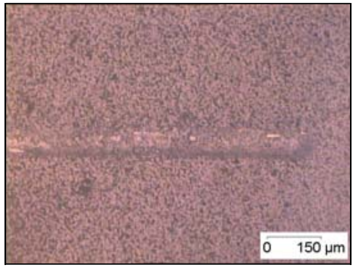
Total failure 47N

AlTiN – 10N to 58N



40N to 76N

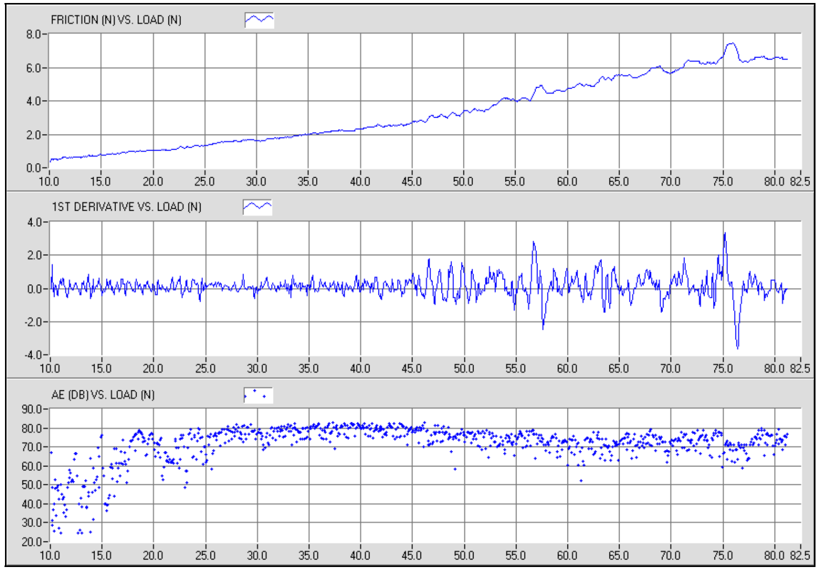


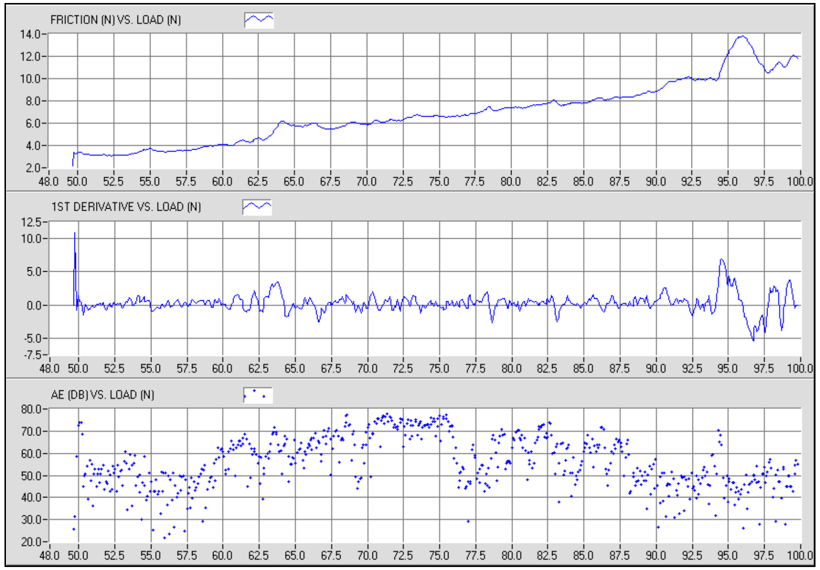


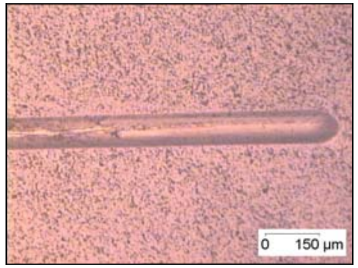
Total failure >76N
Some cohesive patches in track

AlTiN + PLC – 10N to 81N

50N to 100N





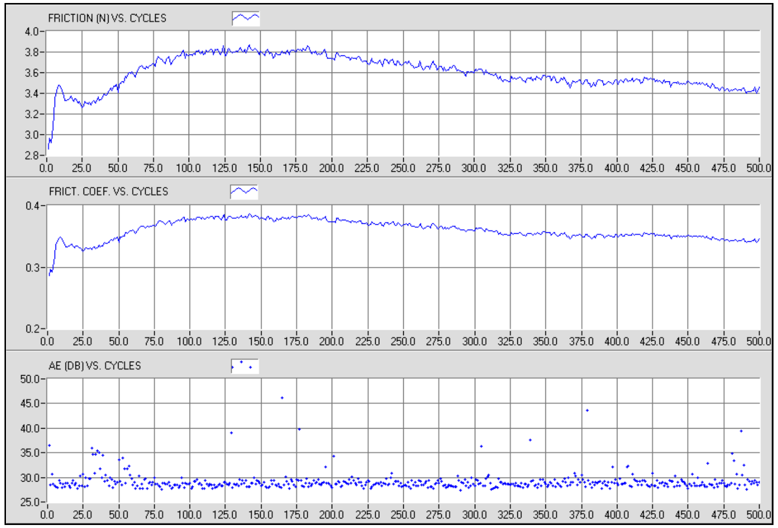


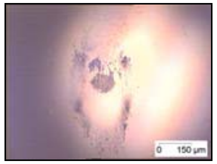
Initial failure 95N
Total failure >100N
Some cohesive patches in track

3.3 Bi-directional wear test

Ø5mmTeflon ball, 10N Load, 150mm/min. linear velocity, 2mm linear displacement, 500 cycles

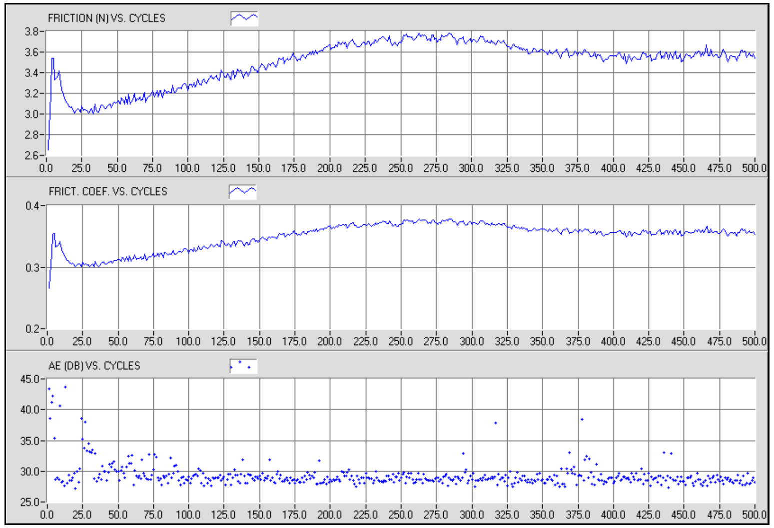
TiN

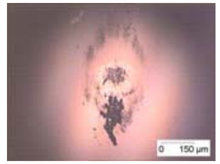




Ball surface after test

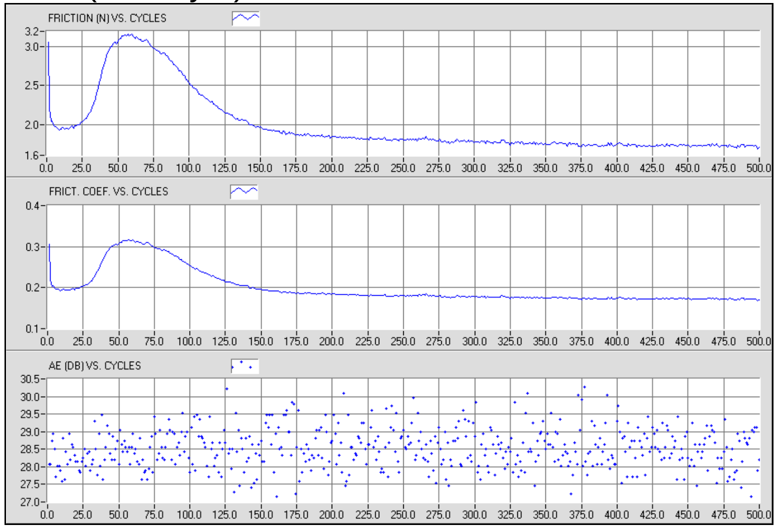
TiCN

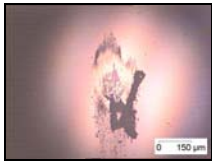




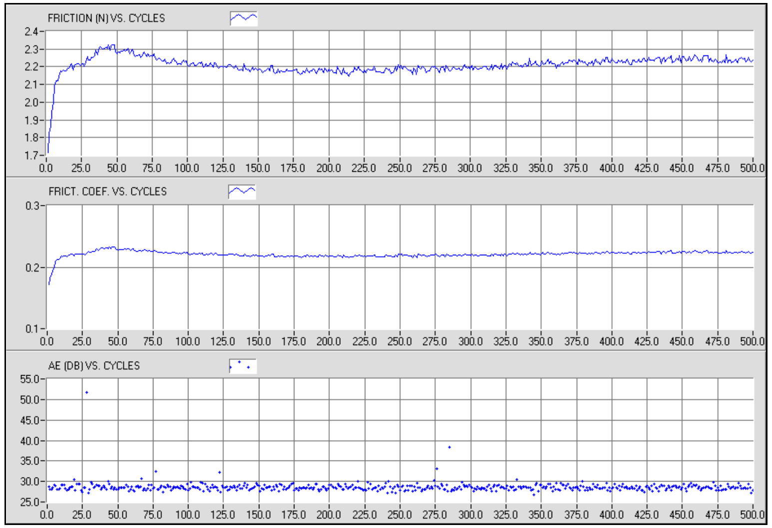
Ball surface after test

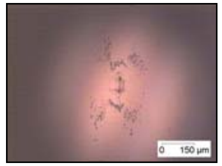
TiCN (multilayer)



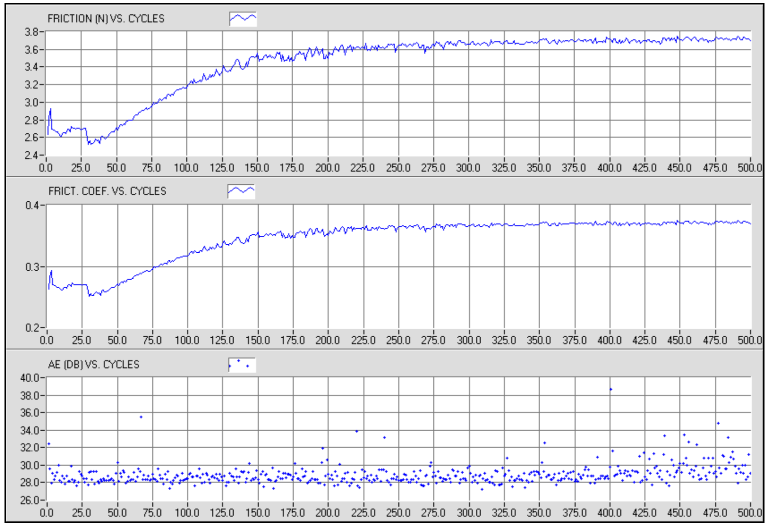


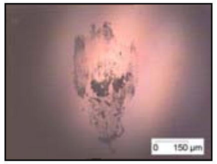
TiBCr



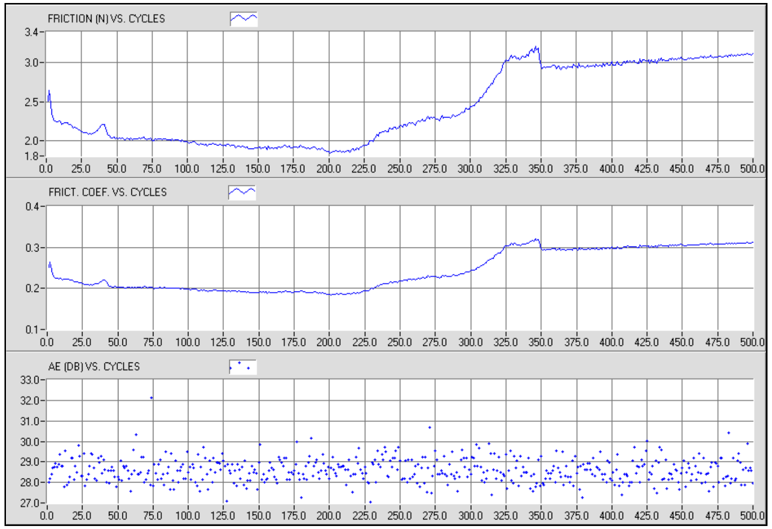


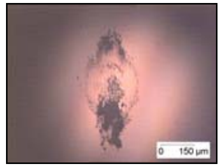
AlTiN





AlTiN + PLC





4. Conclusions

The ball crater test shows the different layers in each of the coatings, each layer can be calculated using this method. Because most of the samples were very small two scratch tests were performed 10N to 60N and then another scratch up to 100N. The TiN, TiCN (multilayer) and the AlTiN coatings performed well in the scratch test with Total failures above 70N. The other coatings showed a rise in friction toward the end of the test indicating initial failure. On the whole all the coatings except the TiBCr showed good adhesion. For the multipass tests all the coatings survived the 500 cycles under a load of 10N. The TiBCr coating produced the lowest steady friction coefficient and the least amount of ball wear.

Automatic reports are also generated by the scratch tester for each test.