Achieving Ultra-low friction with a-C coatings

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Aims and Objectives

Aims: To investigate the tribological performance of amorphous (a-C) coating and try to achieve ultralow friction by different tribological measures.

Objectives:

1. Deposition and characterization of a-C coating by physical vapor deposition (PVD) technology.
2. Tribological tests of a-C coating by tribometers under boundary lubrication regime.
3. Achieving ultralow friction by different tribological measures

Background

Why try to mitigate friction?

- Friction and wear contribute to major energy and material losses
- Friction and other phenomena are considered to account for nearly 20% of the total energy consumption globally, each year (1).
- Berman et al suggests reducing frictional losses by 30% a year would result in energy savings of 2.46 billion kWh/year (2).
- Therefore, the aim to reduce friction has become an area of high interest.

Mechanisms of Friction

Friction is influenced by many different parameters and some of these can be quite difficult to mitigate depending on the application. Figure 1 shows these factors.

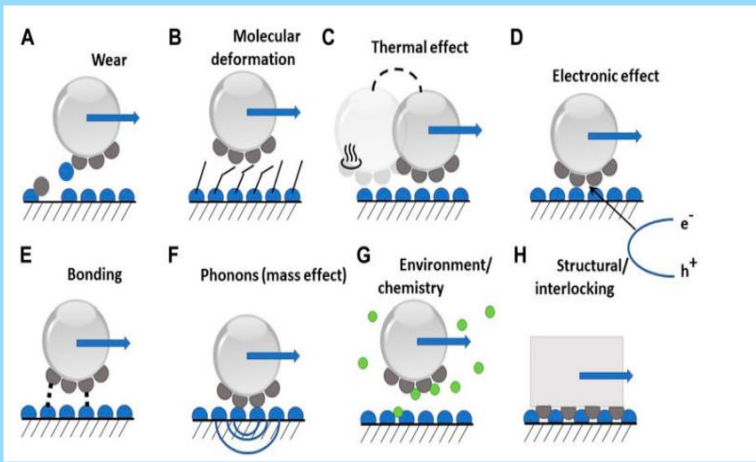

Figure 1 – Factors contributing to friction (3)

What is ultra-low friction?

Ultra-low friction occurs when the coefficient of friction between two sliding surfaces is ≤ 0.01, this is sometimes referred to as superlubricity.

Coatings that achieve ultra-low friction are applicable in many fields of industry, ranging from aerospace to electronics.

DLC Characterisation

The DLC coating was applied using the Hauzer Flexicoat 850. The coating structure is shown in table 1.

Coating thicknesses were calculated using a calo tester with a 30 mm diameter ball.

Table 1 – Coating Structure

Composition	Layer Thickness (μm)
1) Cr	0.636
2) Cr + WC	0.533
3) WC:H	0.122
4) DLC:H	0.576

Rockwell C hardness tests determined the coating had a hardness of 62.44 HRC. The indent can be seen in figure 3, which shows great adhesion of the coating at HF 1-2.

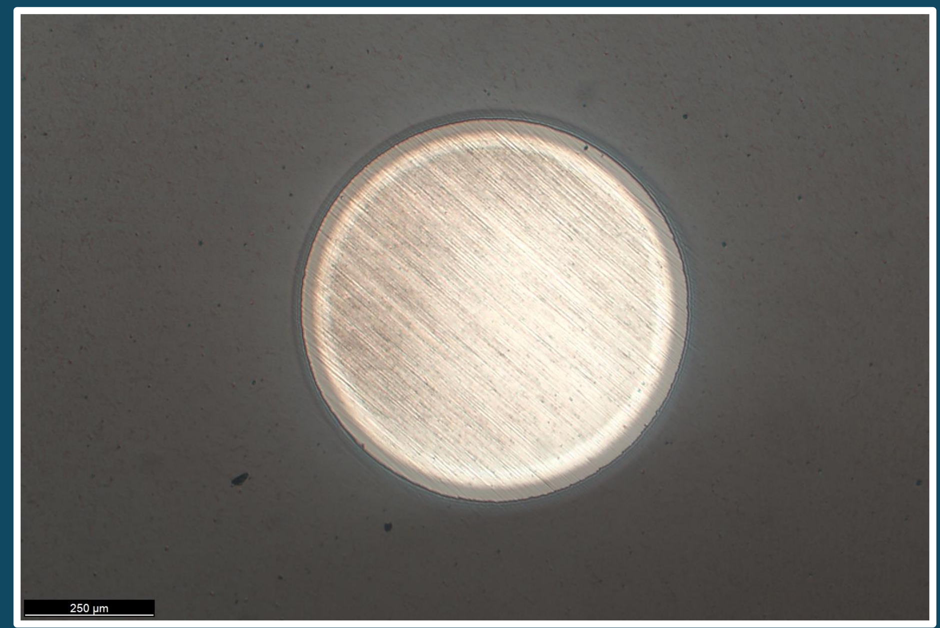

Figure 2 – Crater from the calo tests on the DLC coating

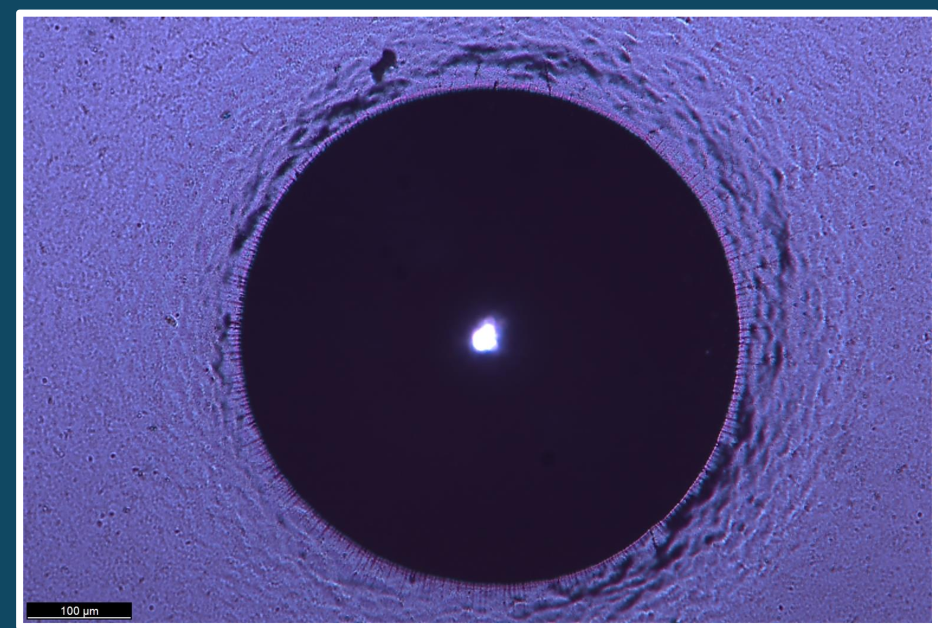

Figure 3 – Indent created by Rockwell C hardness tests

Friction Results

Reciprocating friction tests were conducted on a Bruker UMT tribometer. Figures 4-7 show 4 of the test results. The CoF of the lubricated tests was much lower than the CoF for the dry sliding test, up to ~10 times lower.

Test parameters & conditions:

- 10 mm stroke length
- 1 hr duration with 6 mm ball bearing
- 18°C and 70% humidity

Raman Spectroscopy

Raman spectroscopy showed that for the dry sliding tests, the coating experienced changes in the structure of the DLC, figure 8.

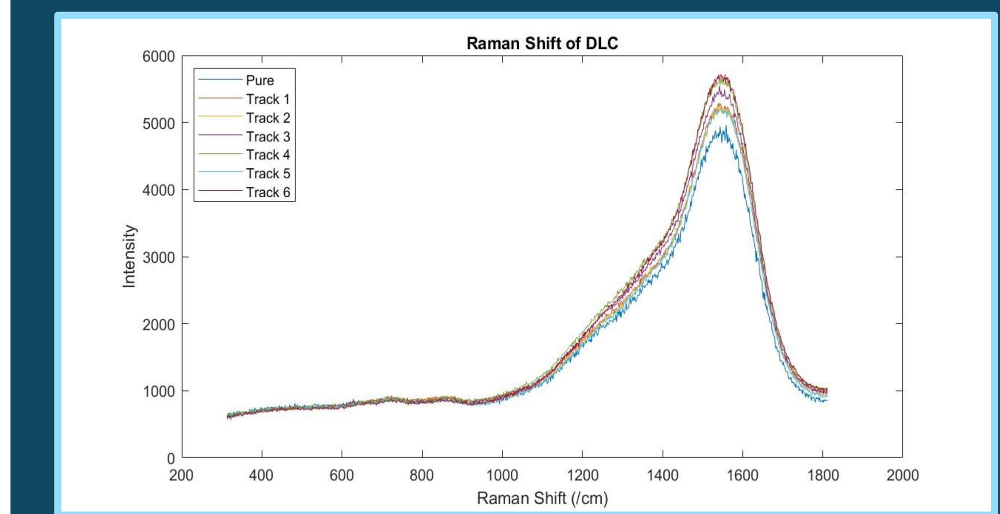

Figure 8 – Raman Shift of the DLC sample for dry sliding conditions

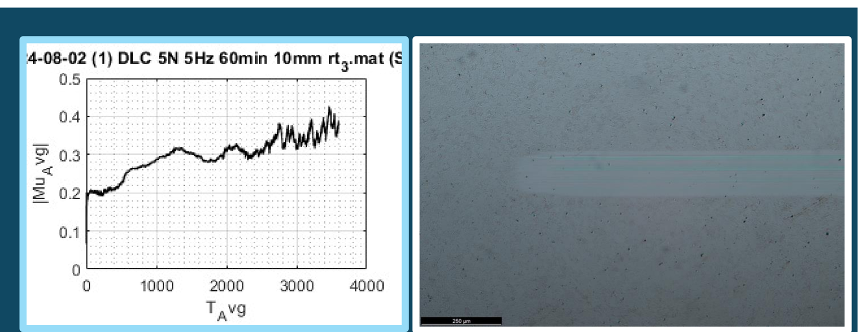

Figure 4 – CoF plot (a) wear scar (b) of dry sliding 5N 5Hz test

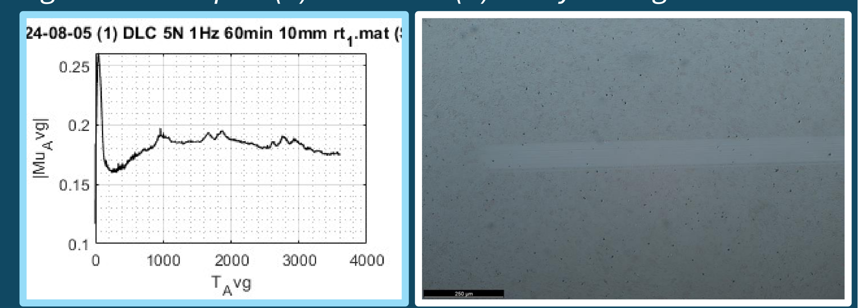

Figure 5 – CoF plot (a) wear scar (b) of dry sliding 5N 1Hz test

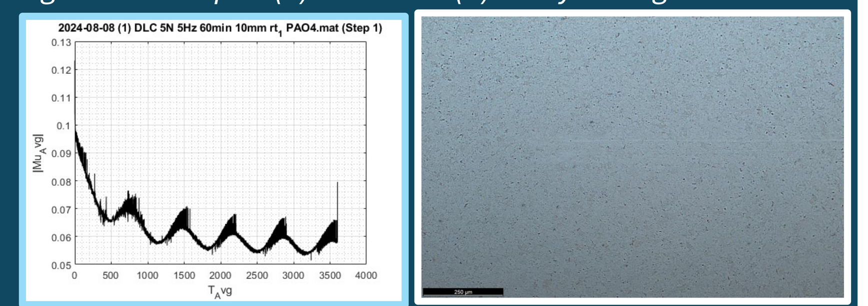

Figure 6 – CoF plot (a) wear scar (b) of PAO4 5N 5Hz test

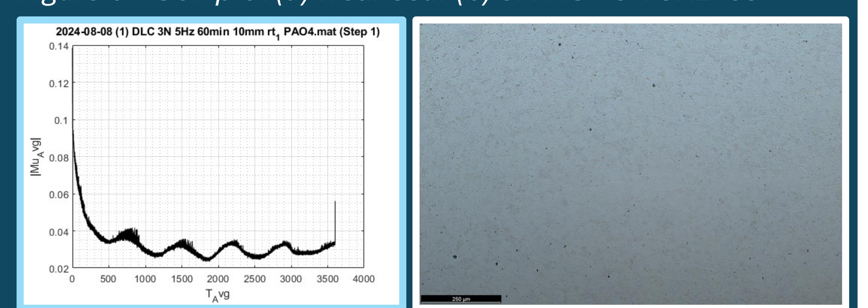

Figure 7 – CoF plot (a) wear scar (b) of PAO4 3N 5Hz test

FEA Analysis

Development of a FEA model to simulate the performance of DLC coating was difficult.

The first step was simulating the indentation of a ball into a HSS sample with and without the DLC coating, shown in figure 9.

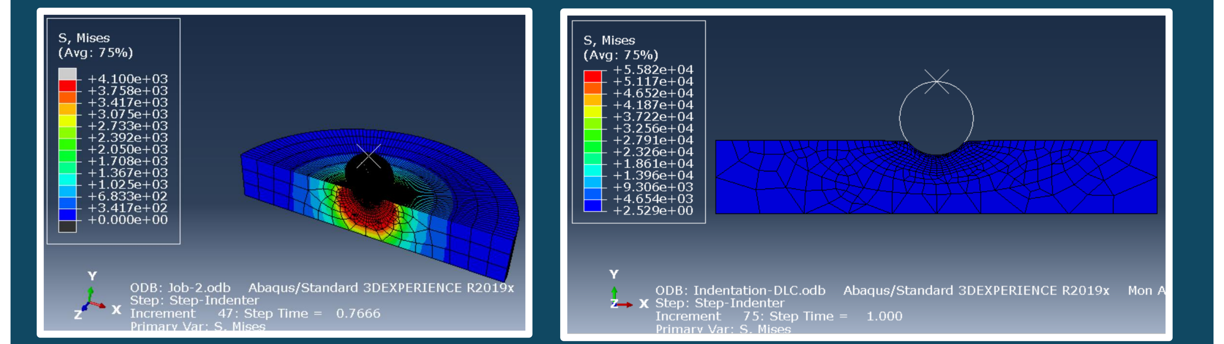

Figure 9 – FEA models showing no coating (left) and a DLC coating (right) experiencing an indentation

The development ran into difficulty when attempting to simulate the sliding of a ball on the sample.

The FEA model is in very early stages and so no accurate results have been obtained during the duration of the internship.

Conclusions & Further Work

The friction test results showed promising signs to achieve superlubricity, the best CoF achieved by the lubricated tests was ~0.03.

Work to reduce this CoF further will look at introducing additives into the PAO4 oil in addition to using other lubricating oils/techniques.

Work on the FEA model will also be developed to attempt to accurately represent the behaviour of the DLC coating from tribo-mechanical perspective.

References & Acknowledgements

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