

Characterisation of automotive bore material and coatings using Atomic Force Microscopy

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1. Introduction

Choosing in-cylinder surfaces is complex. A well-chosen surface has low friction and wear. Conversely, oversight often leads to premature failure. Identification of appropriate surfaces is typically conducted in an empirical manner or through mimicry of tried and tested exemplars found in current engineering practice. This paper demonstrates the use of Atomic Force Microscopy in Lateral Force Mode to characterise typical cylinder bore/liner materials and coatings. The approach integrates LFM with continuum contact mechanics. The real contact area and effective elastic modulus of the surface, including the effect of any reactive surface film are evaluated. Surface energy and shear strength, as well as the coefficient of friction at the nanoscale are also determined. These properties are measured for 6 cylinder bore materials, including for composite Nickel-Silicon Carbide and DLC, used for high performance engines.

2. Methodology/Results/Discussion

Lateral Force Microscopy is used to measure and benchmark the frictional performance of six specimen materials, which are most commonly used as the primary working cylinder bore/liner surfaces for a wide range of internal combustion engines. The friction force is measured with lateral force microscopy over a number of scan areas ($1 \times 1 \mu\text{m}^2$). The boundary shear strength (τ) of material is determined by modelling the frictional force data with DMT [1] theory; i.e. using equation (1).

$$F_f = \tau A = \tau \pi \left[\frac{3R(F_N - F_{ad})}{4E^*} \right]^{2/3} \quad (1)$$

where, R is tip radius, F_N is normal load, F_{ad} is measured adhesive force and E^* is measured reduced elastic modulus of the surface through indentation with AFM. More information on this procedure is reported by Umer et al [2]. The Scanning electron microscope image for one of the sample; i.e. Nickel-Silicon Carbide coated sample is shown in the figure 1.

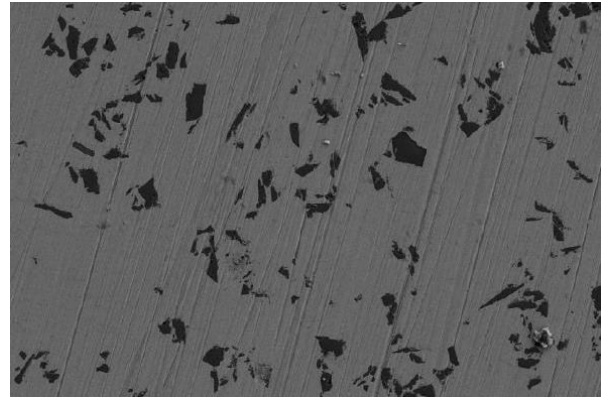


Figure 1: Scanning electron microscopy image of Nickel-Silicon Carbide at area of $55 \mu\text{m} \times 30 \mu\text{m}$

The results show the dependence of nano-scale frictional performance of each material with predicted contact area. The elastic modulus and surface energy of the individual surfaces are used to explain the variations in frictional performance.

The electroplated Nickel-Silicon Carbide surface, which is used extensively in race engine applications, is shown to exhibit lowest friction primarily as a result of its relatively low interfacial shear strength.

Acknowledgement

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References

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