DLC coatings for cam follower applications: The role of the surface on tribochemical reactions, friction and wear

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ABSTRACT – In this study, the tribological properties of steel, Mn-phosphate, Si doped (S1s), and hydrogenated tetrahedral amorphous carbon (ta-C:H) diamond like carbon (DLC) coatings were investigated in a pin on reciprocating plate tribometer and single cam test rig. S1s and taC-H DLC coating architectures were obtained with plasma assisted chemical vapor deposition technique with hardness 20 ± 4 GPa and 35 ± 7 GPa respectively. All materials had a centre-line average surface roughness (R_a) of 0.02-0.03 µm except for the $Mn(PO_3)_2$ which had R_a of 0.30 µm. The S1s showed severe delamination after tests on the reciprocating tribometer while spots of wear flakes were observed in the bench test. Both single cam rig and reciprocating tests have shown similar wear and friction results which can be used to rank materials, surface coatings and lubricants for optimum performance of valve train components.

1. INTRODUCTION

The current trend in the automotive industry is to adopt designs, materials and surface treatments that lead to the development of more efficient engines with low friction, improved wear and reduced fuel consumption [1]. This can be achieved in two folds; firstly by the reduction of the overall weight of engine by selection of the lighter materials. This method effectively reduces the dynamic loads which significantly reduces fuel consumption. A prime example was demonstrated by Kanzaki and coworkers [2] where tappets and spring retainers were replace with lighter aluminium materials and a 40% reduction in friction torque was achieved in the valve train. The second method employs specialized coatings particularly diamond like carbon (DLC) coatings which minimise the friction and wear on interacting components in both dry and lubricated contacts.

This report characterises different DLC coatings for their ability to interact with the oil and produce boundary/mixed nanoscopic tribofilms necessary to reduce friction and wear. All coatings had similar centre line average roughness (R_a = 0.02 µm) to ensure that the friction/wear and tribochemical responses were due to the coating properties and not the roughness.

2. MATERIAL AND METHODS

The substrate material for all tests was 16MnCr5 (steel) which was coated with soft running-in Mn-phosphate, S1s and taC:H. They all had varying thickness of 0.5-1.5 µm for $Mn(PO_3)_2$, 2.0 µm for S1s and 1.5 µm for taC:H respectively . The camshaft is a chromium chilled cast iron with lobes having R_a 0.02-0.03 µm. Lubricants used in this setup are 5W30 fully formulated oil FFB, FFA and a group III base oil as reference.

3. OUTLOOK

S1s experiences severe delamination in both reciprocating test (Figure 1) and motored single cam rig test, the S1s coating showed some spots of removed flakes after 50 hrs of testing (See Figure 2) while the taC-H appeared unchanged (no wear) with improved frictional properties [1]. Post mortem surface analytical tests of XPS, AFM and TEM were used to investigate the tribo-chemical films which have been formed on the surface and the interactions of the engine oil with the coating architectures of Mn-phosphate Si doped and taC-H DLC coatings. Tribological test results are discussed in detail particularly in relation to the tribofilms formed around the cam lobes.

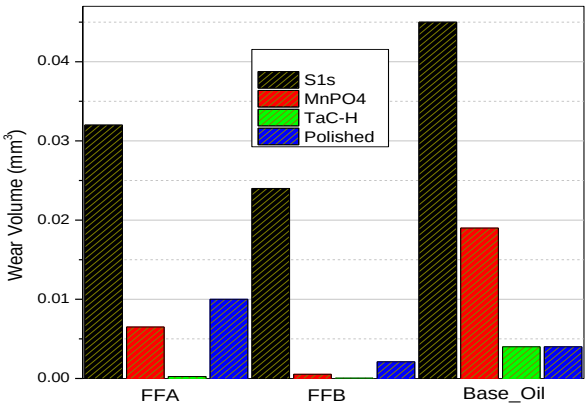

Figure 1 Effects of oil type and coating treatment on wear volume.

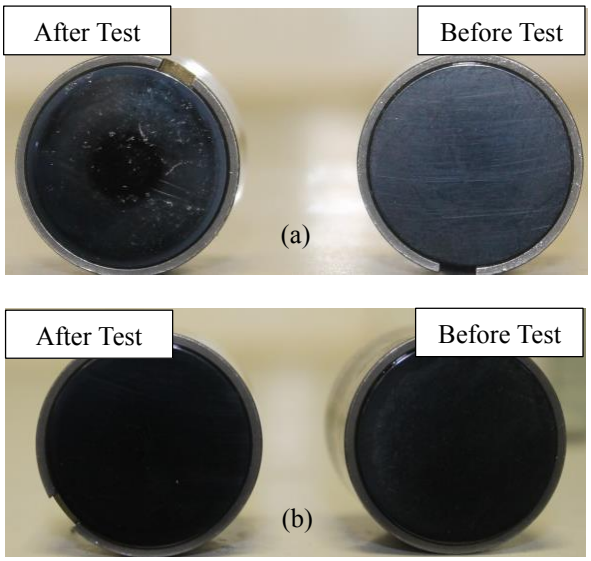

Figure 2 Photo Image (a) S1s coating and (b) taC-H after 50 hrs testing on motored single cam rig.

4. REFERENCES

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