Hydrogen-free DLC-Coated Engine Valve Lifter

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1. Introduction

One effective way to improve the fuel economy of vehicles is to reduce the mechanical losses that occur in internal combustion engines. Reducing friction between the cam and valve lifter in a direct-acting valvetrain contributes substantially to improving fuel economy especially in the practical speed range of everyday driving. This is because such friction accounts for a large 15-20% of total engine friction in this low speed range. Since the lubrication state at the sliding surface between the cam and valve lifter is in the boundary or mixed lubrication region, smoothing their surface roughness so as to reduce their real contact area and reducing the friction coefficient at the contact points by applying a solid lubricant are effective ways of reducing friction between them. The authors have developed and applied a hydrogen-free diamond-like-carbon (DLC) coating for this purpose, focusing on its smoothness, high hardness and solid lubricity effect. As a result of applying this coating to the valve lifter, it was found that friction with the cam was markedly reduced, which contributes to improved fuel economy.

2. Technical details

Figure 1 shows a cross-sectional photo of an engine cylinder head and a photo of a valve lifter coated with the hydrogen-free DLC coating. The DLC coating is applied to the valve lifter crown that slides on the cam lobe surface.

Figure 2 shows the results of pin-on-disk (POD) friction tests conducted on test pieces. It is seen that the friction coefficient declined as the hydrogen content of the DLC coating was reduced, with the lowest value being displayed by the hydrogen-free DLC coating (a-C coating). That result is attributed to the suppression of metal contact at the sliding surface owing to accelerated adsorption by the a-C coating of oiliness agents in the engine oil. Since the engine oil used in this evaluation contained many additives besides the oiliness agents, an investigation was made of the potential friction reduction obtainable with a combination of the a-C coating and oiliness agents. For that purpose, 1 wt% of glycerin-mono-oleate (GMO) was added to a synthetic poly-alpha-olefin (PAO) oil as an oiliness agent to produce a prototype oil for use in conducting a POD evaluation. The results are shown by the dashed line in Fig. 2. The friction reduction effect became more pronounced with a lower hydrogen content and friction was reduced by as much as 75% compared with the result seen for a conventional 5W30 engine oil.

To confirm the friction reduction effect in an actual engine, measurements were made of the camshaft friction torque in a V6 engine and the results are shown in Fig. 3.

To separate the effect of the surface roughness, the results are plotted in relation to the combined roughness of the cam and valve lifter following the test. The combination of the a-C coating and 5W30 engine oil showed the lowest level of friction torque. The result can be explained in terms of the improvement of the combined surface roughness together with the solid lubricity effect of the coating. The combination of the a-C coating and the PAO + GMO prototype oil had the effect of reducing friction by approximately 60% compared with a phosphate coating. This indicates that there is a large potential for reducing friction through further engine oil improvements.

3. Conclusion

The hydrogen-free DLC-coated valve lifter was first applied to a new V6 engine that was released in the fall of 2006, together with the use of a DLC-compatible 5W30GF4 fuel-saving engine oil. The application of this valve lifter will be expanded to other engines in the near future, and it is also planned to expand the application of the a-C coating to piston rings and other sliding parts.

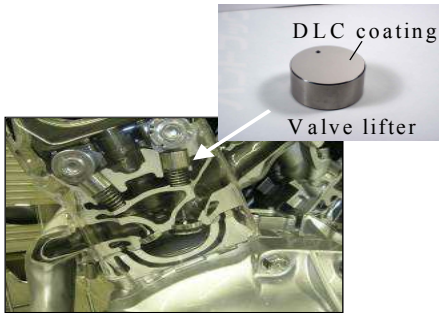

Fig.1 Cross-sectional photo of engine cylinder head DLC coating

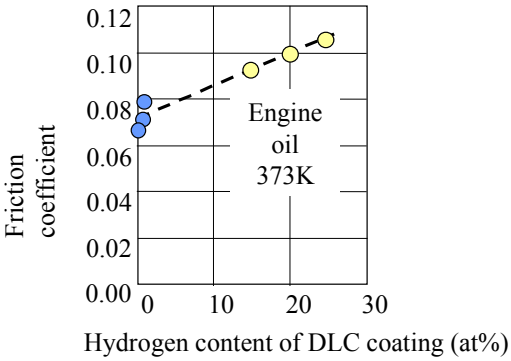

Fig.2 Friction coefficient vs. hydrogen content of DLC coating under a lubricated condition

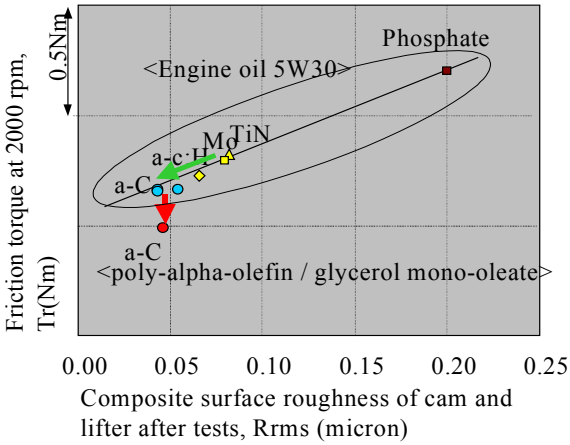

Fig.3 Results of cylinder head rig tests for combinations of different coatings and different oils