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Title(English)	Study on Tribofilm Formation and its Friction Characteristics Caused by Promotive and Inhibitive Action between Various Lubricating Additives and Functionalized Polyalkylmethacrylates in Low Viscosity Engine Oils
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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	Huang Chao	審査員主査： Chief Examiner	青木才子

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis with the title "Study on Tribofilm Formation and its Friction Characteristics Caused by Promotive and Inhibitive Action between Various Lubricating Additives and Functionalized Polyalkylmethacrylates in Low Viscosity Engine Oils"consists of the following 6 chapters. The structure and key points of each chapter are described below.

Chapter 1 is an introduction that explains briefly about background of the development on low viscosity engine oils, friction mechanism under boundary lubrication and additives in engine oil. An overview on the effects of coexisting additives on ZnDTP. Finally, objectives and Structures of thesis are given. In order to improve fuel efficiency for automobiles, it is necessary to reduce undesirable friction loss in automotive engine components by using low viscosity engine oil. Besides, in order to maintain or improve antiwear performance by using the low-viscosity engine oil, it is also necessary to clarify the effects of coexisting additives on the formation and the friction and wear-redusing performance of tribofilms from the low-viscosity oil. In this study, focusing on polymethacrylate (PMA)-series friction modifiers, also used as viscosity modifiers, the formation of tribofilm and its friction and wear characteristics was investigated based on tribochemical reactions among various additives such as ZnDTP, MoDTC, and PMA-series friction modifiers, to achieve reduction in friction with the low-viscosity engine oil.

In chapter 2,"Effect of additive combinations on the tribofilm formation and the friction and wear reducing performance of fully formulated 0W-8 oil", six kinds of 0W-8 engine oil with the absence Ca-based detergent, dispersant or of MoDTC were selected to study their effects on the tribofilm formation and friction characteristics of fully formulated low-viscosity oil. As results, Ca-based detergent in fully formulated 0W-8 oil showed the antagonistic effect on ZnDTP and MoDTC-derived tribofilm. Dispersant showed the antagonistic effect in fully formulated 0W-8 oil without MoDTC while showed some synergistic effect on ZnDTP-derived tribofilm formation with the presence of MoDTC. Under different additive combinations, the addition of MoDTC had different effects on the ZnDTP-derived tribofilm formation.

In chapter 3,"The tribofilm formation and the tribological characteristics of fully formulated 0W-8 oil in the coexistence with the functionalized polymethacrylate", four kinds of PMA, with either no functionalized groups or with an amino, hydroxyl, or carboxyl group, were selected to study their effects on the tribofilm formation and friction characteristics of fully formulated low-viscosity oil and the change over time. As results, PMA with functionalized groups significantly increased the uniformity of the

tribofilm and reduced the friction coefficient and wear in fully formulated oil. The addition of PMA-OH and PMA-COOH generated longer polyphosphate chain length, more calcium and less sulfur and zinc could significantly reduce friction and wear. The addition of PMA-N generated longer polyphosphate chain length in earlier period to significantly reduce friction and wear. While with the coordination complex formation during further friction, the anti-wear tribofilm lost the durability.

In chapter 4, ”Effect of friction modifiers with polar group on tribofilm formation and the tribological characteristics of the fully formulated 0W-8 oil”, Three kinds of organic friction modifier with polar groups (amino, hydroxyl, or carboxyl) and one inorganic friction modifier were selected to study their effects on the tribofilm formation and friction characteristics of fully formulated low-viscosity oil. As results, Polar group could increase polyphosphates chain lengths in fully formulated 0W-8 oil both organic and inorganic friction modifiers. DMODA and ola showed complex effect that chain length of polyphosphates increased while P, Zn and S from ZnDTP-derived tribofilm were reduced. PMA with and without functionalized groups significantly increased the length of polyphosphate chain to have thicker deposited films in fully formulated oil with MoDTC. While the addition of PMA-OH and PMA-COOH reduce sulfur in fully formulated 0W-8 oil which reduced the ratio of MoS_2.

In chapter 5, “Statistical analysis on the correlation between the elemental intensity of tribofilms and the corresponding coefficients of friction obtained with fully formulated 0W-8 engine oils”, Pearson’s linear correlation coefficient (r) and linear logistic regression were used to clarify the relationship between the intensity of each element and the friction in the generated tribofilm. From the result of Pearson correlation, Ca intensity was positively correlated P and O. Ca is supposed to be calcium polyphosphates and CaO in tribofilm. Linear regression equation was established as $\text{Friction coefficient} = \text{constant } 0.0790 - 0.000278 \times \text{Ca} - 0.00383 \times \text{Mo}$. The mechanism that PMA-OH and PMA-COOH have synergistic effect on ZnDTP-derived tribofilm in fully formulated 0W-8 oil is, PMA-OH and PMA-COOH could increase the concentration ratio of neutral ZnDTP while promoting more CaO formed on the surface to promote longer chain polyphosphates formation.

Chapter 6 is the summary of thesis, which includes the general conclusion of this research and the considerable issues concerning the present research for further.