

Characteristics of Lubricants on Auto-ignition under Controllable Active Thermo-Atmosphere

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ABSTRACT

Downsizing gasoline direct injection engine with turbo boost technology is the main trend for gasoline engine. However, with engine downsizing and ever increasing of power output, a new abnormal phenomenon, known as pre-ignition or super knock, occurs in turbocharged engines. Pre-ignition will cause very high in-cylinder pressure and high oscillations. In some circumstances, one cycle of severe pre-ignition may damage the piston or spark plug, which has a severe influence on engine performance and service life. So pre-ignition has raised lots of attention in both industry and academic society. More and more studies reveal that the auto-ignition of lubricants is the potential source for pre-ignition. The auto-ignition characteristics of different lubricants are studied. This paper focuses on the ignition delay of different lubricants in Controllable Active Thermo-Atmosphere (CATA) combustion system. In this study, many tests were conducted in the CATA combustion system. The result of tests shows that with the increase of the temperature, the ignition delay of the oil decrease obviously. And the results of tests show that with the increase of the kinematic viscosity, the ignition delay increase. But with the increase of the calcium content, the ignition delay decrease drastically. And the evaporation loss has almost no influence on the ignition delay of the oil.

Different lubricants have different auto-ignition characteristics, which may influence the pre-ignition frequency in gasoline engine. The Controllable Active Thermo-Atmosphere (CATA) is proved to be an effective facility to study the auto-ignition characteristics of lubricants.

CITATION: Fan, C., Tong, S., Xu, X., Li, J. et al., "Characteristics of Lubricants on Auto-ignition under Controllable Active Thermo-Atmosphere," *SAE Int. J. Fuels Lubr.* 9(2):2016, doi:10.4271/2016-01-0889.

INTRODUCTION

Pre-ignition refers to the auto-ignition of fuel-air mixture before spark timing, which is a kind of abnormal combustion phenomenon happening at low engine speed ($<3000\text{r/min}$) and high load ($\text{BMEP}>1.0\text{MPa}$). These pre-ignitions have high randomness and may lead to super knock, whose peak pressure is higher than twice of the normal combustion and causes severe engine damage. Since there is currently still no definite conclusion on the mechanism of pre-ignition, pre-ignition becomes a limit for the engine downsizing and the improvement of power density.

According to some researchers [1, 2, 3, 4], the octane value, volatility of gasoline, intake timing, injection strategy and EGR rate have impact on the frequency of the pre-ignition occurrence. It is widely

accepted, that the mixture of fuel and lubricant oil through complicated physical and chemical reaction auto-ignites before the spark timing, as a source of pre-ignition. Therefore, research for the chemical and physical properties of lubricant oil is important for study of pre-ignition.

Welling et al. [2] had experiments on nineteen lubricant base stocks and nine lubricant additives in a 4-cylinder engine. The results showed if the lubricant has higher density or viscosity, the frequency of pre-ignition occurrence goes down. In addition, no significant difference of pre-ignition occurrence was observed when the lubricants had different aromatics content. Manfred Amann et al. [5] found that most finished lubricant oils have high octane number, are highly reactive and therefore are expected to be prone to auto-

ignition. Nihon University Graduate School and Idemitsu Kosan Co. Ltd [6, 7] found that Zn-based and Mo-based lubricant additives had no significant impact on auto-ignition. However, the Ca-based lubricant additive had the tendency to promote auto-ignition and abnormal combustion. Yasuo et al.[8]proposed that the calcium in a lubricant changes into CaO particles by burned in the cylinder and these CaO particles absorb CO_2 during the compression stroke with an evolution of heat, becoming a source of pre-ignition.

The mechanism of pre-ignition is currently not completely resolved and many researches are based on the test on an engine or a rapid compression machine. In this paper a Controllable Active Thermo-Atmosphere (CATA) combustor is employed to study on the influence of lubricant content on auto-ignition, in order to reveal the relationship between auto-ignition and pre-ignition of engine. In this research, several types of lubricant oil were tested at certain temperature points, in order to find out the difference of the auto-ignition properties and ignition delay time of different lubricant oil.

EXPERIMENTAL SETUP

Controllable Active Thermo-Atmosphere (CATA)

The main part of the CATA combustion system is the combustor (Robert W. Dibble invented at UC Berkeley), as shown in Fig.1. The other parts include three-dimensional positioning system, gas supply system, cooling system, safe operating system, acquisition system, high-speed photography system and high pressure injection device[9].

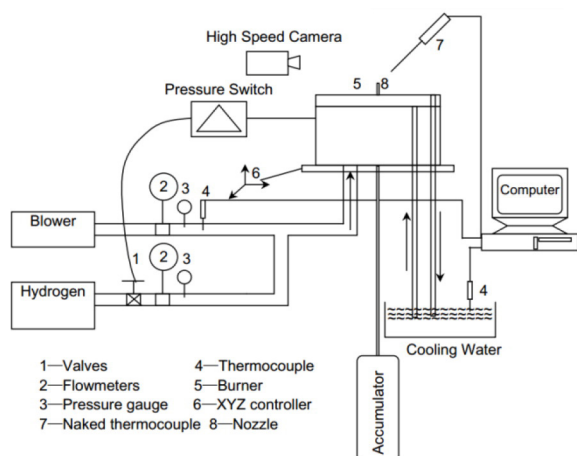
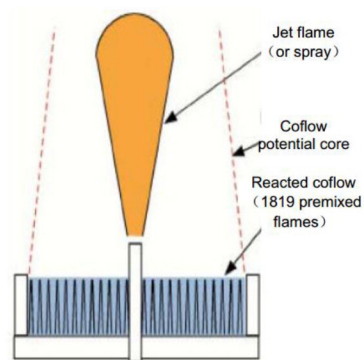


Fig. 1. CATA combustion system

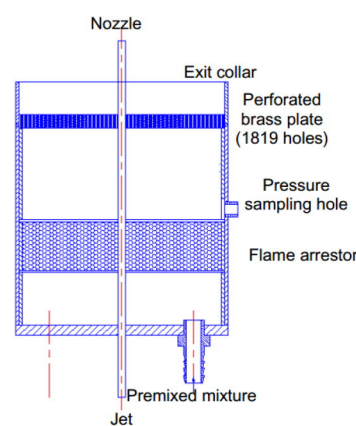
Deng et al[10] remanufactured Dibble burner and built a new one. Fig.2 shows the Schematic and configuration of the burner.

Lubricant oil is ignited by the high and homogenous temperature atmosphere, which is produced by combustion of the mixture of oxygen and hydrogen. The high-speed camera is fixed to shoot the combusting process of lubricant oil. During the experiment the focus and exposure remain unchanged. A quick-response thermocouple is used to measure the temperature of a certain point in the thermo-atmosphere. By changing the fuel air ratio of the oxygen and hydrogen, a continuously changeable temperature atmosphere is created and 1819 premixed flames keep the same temperature at every place of the burner. So the temperature measured by the thermo-

coupler is the same with the temperature of the tested lubricants in the center of the burner. And the ignition delay of tested lubricants can be measured at different temperature.



a. Schematic and Configuration of CATA



b. Configuration of the burner

Fig. 2. Schematic of CATA Burner

Lubricant Oil

In the experiment eleven different types of lubricant oil were tested. Every type consists of one or two lubricant base stocks and detergents with different proportion. There are altogether four different lubricant base stocks (Type I to Type IV) and 2 lubricant detergents (Salicylate and Sulfonate). Table 1 shows the ingredients of the eleven lubricant oils.

Table 1. base stocks and additives of the various lubricants

Number	Base stock	additive
1	Type III	Salicylate
2	Type III	Sulfonate
3	Type III	Salicylate
4	Type III	Salicylate
5	Type III	Sulfonate
6	Type II	Salicylate
7	Type I	Salicylate
8	Type IV	Salicylate
9	Type III+10% Type V	Salicylate
10	Type III+10% Type VI	Salicylate
11	Type III	Salicylate