A Study of Preignition in a Highly Boosted Gasoline Engine

Yasuo Moriyoshi, Tatsuya Kuboyama, Koji Morikawa

Chiba University

The authors investigated the reasons of how a preignition occurs in a highly boosted gasoline engine from both experimental and theoretical viewpoints. The experimental apparatus is shown in Fig. 1 while the engine specifications are indicated in Table 1. A visualization of preignition was carried out using an endoscope as shown in Fig. 2. The in-cylinder pressure trace and apparent heat release rate are indicated with direct photographs during preignition initiated by the hot particles. In this cycle, some glowing particles were observed even during early stage of compression stroke, and these glowing particles induced preignition before spark ignition timing. As can be seen in the heat release rate in this figure, heat release was initiated at about -12 deg. ATDC which is earlier than the spark ignition timing set at 4 deg.

As a result, three processes are derived; i) small oil droplets coming out during compression stroke cause autoignition and become the source of preignition, ii) oil droplets coming out during exhaust stroke burn and CaO particle as residue included in oil as an additive becomes the preignition source, and iii) deposits peeled off from the combustion chamber are heated by combustion and become the preignition source in the next engine cycle. Many experimental facts can be adopted to either process. As a result, the reduction of $CaCO_3$ in lubricating oil and preventing oil from coming out into the cylinder are radical solutions to reduce preignitions.

In a lubricating oil, Ca is included in a micelle state of $CaCO_3$. At high temperature, $CaCO_3$ will be thermally decompounded into CaO and CO_2. Meanwhile, CaO particles absorb CO_2 with an evolution of heat and becomes $CaCO_3$ again as expressed by Eq. (1).

$$CaCO_{3(s)} \Leftrightarrow CaO_{(s)} + CO_{2(g)} \qquad ..... \qquad (1)$$

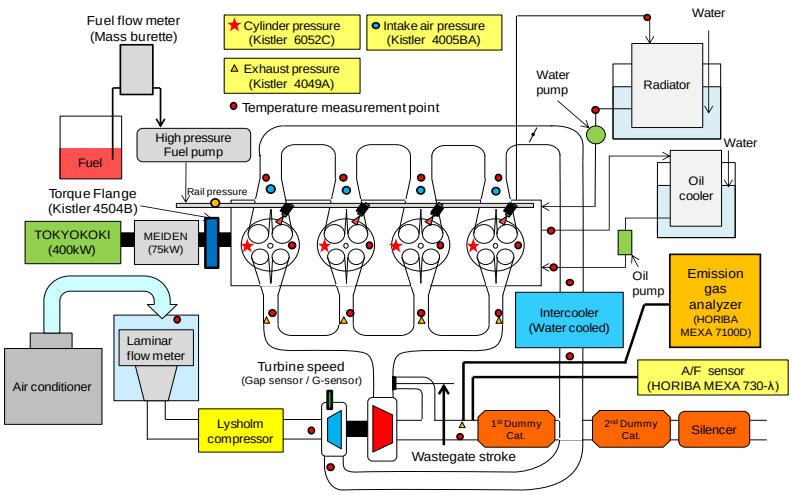

Fig. 1 Experimental apparatus

Bore	79.7	mm
Stroke	81.0	mm
Cylinder	Inline 4	-
Comression ratio	9.49 : 1	-
Conrod length	139.0	mm
Crank diameter	80.9	mm
Piston pin offset	-0.5	mm
Cylinder offset	-9.5	mm
Combustion chamber volume	47.6	cc
Stroke volume	404.2	cc
Total stroke volume	1616.9	cc

Table 1 Engine specifications

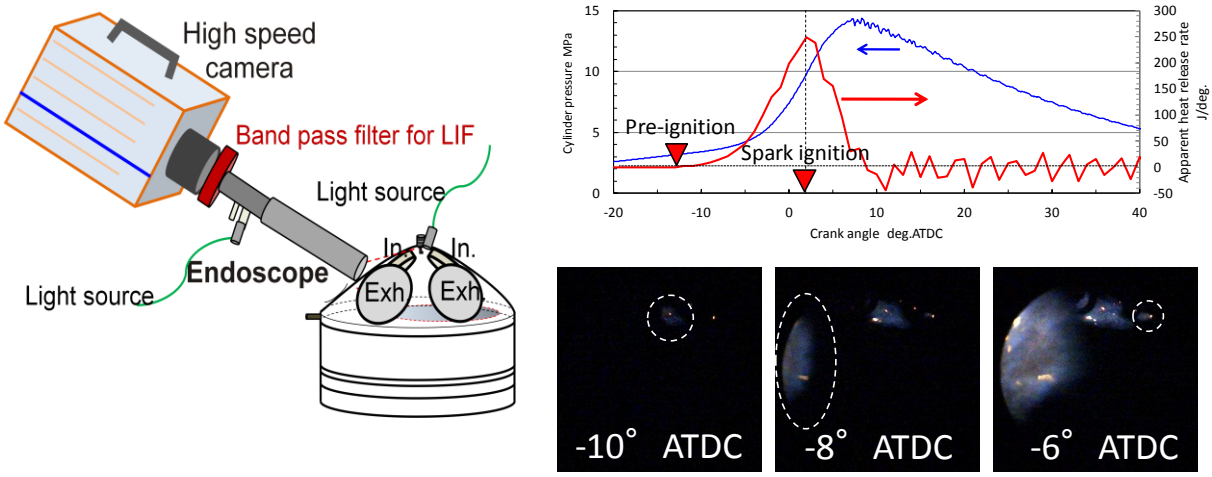

Fig. 2 Visualization field through the endoscope attached to the cylinder head (at BDC)

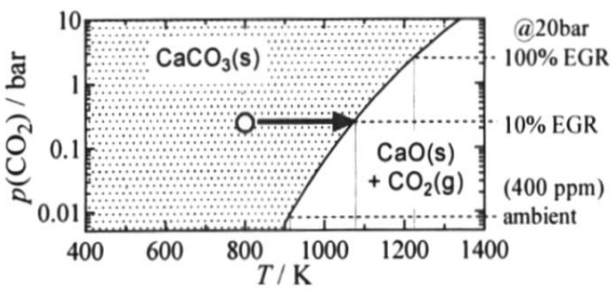

Fig.3 Equilibrium temperature of CaO and $CaCO_3$

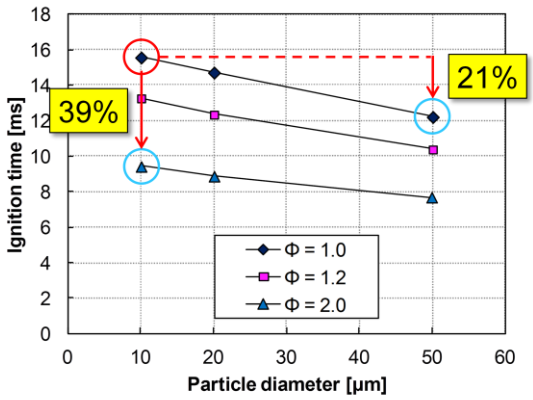

Fig.4 Effect of particle diameter and equivalence ratio on ignition delay

When CaO absorbs CO_2, this exothermic reaction is controlled by the diffusion and adhesion speed of CO_2 on CaO. The equilibrium temperature depending on CO_2 partial pressure is about 900 K in the atmosphere with 400 ppm CO_2. Figure 3 indicates the relationship between the CO_2 partial pressure and the equilibrium temperature.

Figure 4 shows the ignition delay of a particle vs. the diameter with varying the ambient mixture's equivalence ratio. Results without a particle are also indicated. As the particle becomes large, the ignition time becomes short linearly. The slope is slightly steeper with a less equivalence ratio. For example, the ignition delay of 10 μm particle is 15.6 and 9.45 ms at equivalence ratio of 1.0 and 2.0, respectively. The time is shorter in 39 % under a rich condition. Meanwhile, the ignition delay of a 50 μm particle is 12.2 ms at an equivalence ratio of 1.0. The time is shorter in 21 % compared to of a 10 μm particle. This means that the effect of equivalence ratio is stronger than of the diameter. The local equivalence ratio takes about 2.0 at compression TDC around the intake valves as indicated. Thereby, a preignition may occur during the compression stroke by CaO particles.