An Ignition Control of DME HCCI Engine

Seiji SHIBA and Seishiro FUKUTANI

Department of System Engineering, Okayama Prefectural University
111 Kuboki, Soja, Okayama 719-1197, JAPAN
E-mail: shiba@cse.oka-pu.ac.jp & fukutani@cse.oka-pu.ac.jp

Keyword: HCCI Engine, Ignition Control, DME Combustion

Introduction

The investigation of HCCI Engine is more and more developed around the world. The reason is a possibility that the engine is less hurtful for environment. We selected DME fuel for this engine system because of its ignition ability and clean exhaust gas.

Alcoholic fuels and ether fuels are useful because there will be few changed parts on the occasion of application to the existing internal combustion engine. While investigating paying attention to the ignition process of DME about the fuel characteristic more fundamental than carrying out the numerical simulation of the compression ignition process, it aims at acquiring useful knowledge to ignition process control of an internal combustion engine.

Numerical model

The calculation models in this study are mainly non-dimensional chemical reaction calculation without heat loss at fuel-air mixture. The calculation codes for chemical reaction are supported by Chemkin II[1]. The chemical reaction scheme and thermodynamics data are from LLNL Combustion Chemistry Group[2]-[4]. In this case, 336 reactions and 78 chemistry species are used.

In this study we use DME as fuel and 21% oxygen-nitrogen mixture as oxidizer. The definition of ignition delay is considered as the point of inflection of a temperature history. when two or more points of inflection existed, we define the lowest temperature thing low-temperature ignition delay and made the hottest thing total ignition delay. All inhalation and exhaust is considered to be occurred at the bottom dead center instantaneously. In this study we assumed the engine works at 800rpm and the history shows by the crank angle from the top dead center.

Result

Figure 1 shows that two steps of pressure rises were altogether shown in this range, which shows the pressure history in the case of compression ratio 9.0 and initial temperature 320K. It turns out that the time of ignition is the earlier at the lower equivalence ratio.

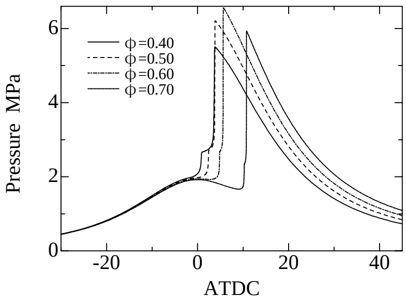

Fig. 1 Pressure history (ε =9.0, T_{ini}=320K, ϕ=0.40～0.70)

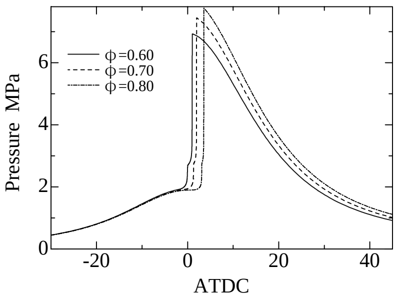

Fig. 2 Pressure history (ε =9.0, T_{ini}=330K, ϕ=0.60～0.80)

Figure 2 also shows the pressure history of the same compression ratio and initial temperature 330K. In this case the staged-ignition timing is earlier than figure 1, because of temperature effect. The equivalence ratio, in which the ignition timing is near TDC is larger than figure 1. For the effective system at this compression ratio, the preheating of the premix gas is indispensable.

In figure 3 shows the influence that the initial temperature and this equivalence ratio affect ignition timing at a compression ratio 9.0. At the whole range, the smaller equivalence ratio causes earlier ignition timing.

This is because the calculation model was performed by perfect heat insulation which shows that larger specific heat at the lower equivalence ratio causes the larger temperature rising with the same compression ratio. This fact shows that the initial temperature and the equivalence ratio is important for operation control of this engine system.

In fact, however the heat insulation in a cylinder is low in other researches and then some experiment results show that the high equivalence ratio causes earlier ignition timing. Therefore from now on in order to aim at stable operation of the engine system , we need to check that ignition timing and to investigate the influence of the wall surface and un-insulating cylinder in detail. At the whole region the higher initial temperature cause earlier ignition timing. In the point of the system stability, it is desirable that there is little change of ignition timing when the equivalence ratio and initial temperature vary, i.e., in the figure 3 the suitable area is where the interval of graph line are the smaller. However as for its efficiency, the ignition near TDC is clearly required.

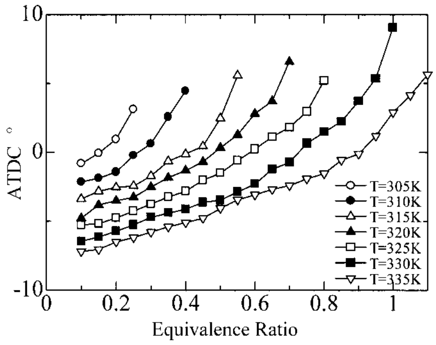

Fig. 3　Ignition timing（ε =9.0）

Figure 4 shows the pressure histories of higher compression ratio. It shows that the compression ratio 12.0 is effective as a result of selecting the conditions, which set up temperature near normal temperature and show suitable ignition timing. Under these conditions, effective ignition timing is obtained for this equivalence ratio in the large range from 0.5 to 0.8.

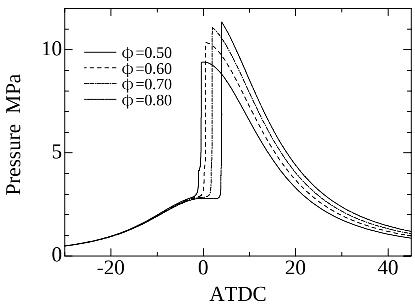

Fig. 4　Pressure history (ε =12.0, T_{ini}=295K, ϕ=0.50～0.80)

The points which only the proper range of ignition timing was finally taken out from Figure 3, and showed the range of this effective equivalence ratio and initial temperature are shown in Figure 5. In this figure, the circle plot shows the proper point that the ignition timing is within 2 degree from TDC.　It is made about 0.2 of equivalence ratio and 5K width of initial temperature and it is thought on the occasion of usual operation that stable operation will probably be possible enough.

Figure 6 shows the temperature at the ignition in the same range of Figure 5.　It shows that ignition temperature is the higher when this equivalence ratio is the lower or the initial temperature the higher.　In the ignition range considered to be proper in Fig. 5, ignition temperature is observed from 690K to 710K.

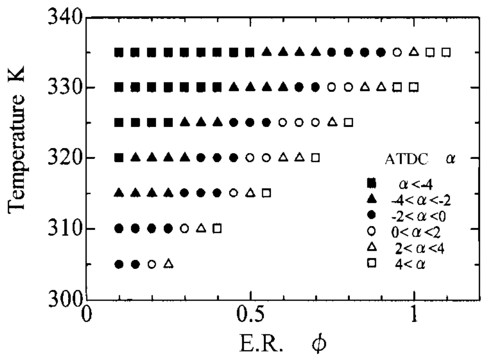

Fig. 5 Area of Ignition timing

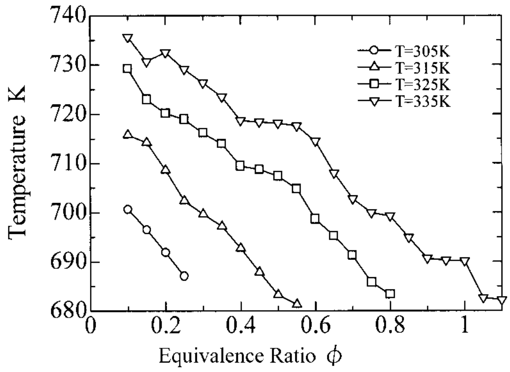

Fig. 6 Ignition temperature

This indicates the possibility of parameter unification to control of ignition timing with two parameters, initial temperature and equivalence ratio.

Since it accepts within wide range of equivalence ratio, it turns out that chemical reaction speed is more dependent on temperature than chemical species concentration.

Conclusion

Non-dimensional numerical simulation of homogenious compression ignition engine system that uses DME as fuel was performed and the following results were obtained.

DME fuel of a LLNL model starts 2-stage combustion in all the ranges of this research

Ignition timing becomes earlier as the equivalence ratio is smaller in the model of this study. It is thought in a more nearly actually model that this influence becomes small.

Also in the initial temperature near normal temperature, proper ignition timing can be obtained with a high rate of compression. It has checked that it was possible to carry out stable operation in this wide range equivalence ratio.

In this study it turns out that the range of the initial temperature is 5K and the equivalence ratio is 0.2 when it maintains ignition timing within 2-degree from TDC. It is thought that active control is not necessary in this range.

The ignition temperature of the DME compression ignition engine with proper ignition timing in this research is from 690K to 710K. This was observed in the large equivalence ratio range.

References

1.R. J. Kee et al., SAND-89-8009, (1989)

2.www-cms.llnl.gov/combustion/combustion_home.html

3.Marinov, N. M, Inter. J. of Chem. Kin. (1998) LLNL, UCRL-JC-131657.

4.Curran et al., Inter. J. Chem. Kinet. 30 229-241(1998) LLNL, UCRL-JC-127071.