A Computational Study to Investigate the Minimum Required Initial Temperature at IVC for Complete Combustion on HCCI Engine Fueled with Natural Gas

Otgonbat Pionyer[1)] · Narankhuu Jamsran[2)] · Ocktaeck Lim[*3)]

[1)] *Institute of e-Vehicle Technology, Ulsan University, Mugeo-dong, Nam-gu, Ulsan 680-749, Korea*

[2)] *Graduate School of Mechanical and Automotive Engineering, Ulsan University, Mugeo-dong, Nam-gu, Ulsan 680-749, Korea*

[*3)] *Department of Mechanical and Automotive Engineering, Ulsan University, Mugeo-dong, Nam-gu, Ulsan 680-749, Korea*

Abstract: This study was clarified the minimum required initial temperature at IVC for complete combustion on HCCI engine fueled with natural gas. There were determined mainly by 99.9% of fuel consumed for complete combustion. The CHEMKIN-PRO was used to perform the numerical analysis. To set boundary of operating range, equivalence ratio 0.4, intake air temperatures from 370K to 450K (refer to fuel mole concentrations), engine speed 1200rpm and fuel compositions was varied from 0 to 20% for each mole fractions. In the result, minimum required initial temperature was reduced when fuel species mole concentrations were increased. Therefore, higher mole concentrations of them support the early HRR and that's helps to ignite easily. There are two factors are affecting the $T_{IVC,min}$ for autoignition occur. 1) the change in ratio of specific heats (ɣ), 2) change autoignition threshold. From here, equivalence ratio, EGR ratio and boost pressures are affected much. In our calculation, when mole concentration of fuel species increased minimum required initial temperatures were slightly degreased. When increased each mole concentrations of fuel species, CO, UHC and HC degreased.

Key words: HCCI (Homogeneous Charge Compression Injection), minimum required initial temperature, natural gas, autoignition

* Corresponding Author, E-mail: otlim@ulsan.ac.kr

1. INTRODUCTION

In an internal combustion engine, which is representative of a spark ignition engine, the diesel engine has been strong demand for low pollution, the use of alternative fuel and oil efficiency. Therefore, new engine technologies must effectively utilize alternative fuels, while maintaining high thermal efficiency and low emission. As next generation engine to satisfy these demands, many researcher has been test on the HCCI engine, which is premixed homogenous charge is compressed until occurring to autoignition. In this study, we were clarified the effects of fuel compositions how to influence the minimum required initial temperature at IVC on HCCI engine fueled with natural gas. Therefore, how the mole fractions influenced on the IMEP and NO_X emission.

2. CALCULATION METHOD

The CHEMKIN-PRO was used to perform this computational study for an HCCI engine. In this calculation, we assumed that the temperature, pressure, distribution of chemical species were completely uniform (single zone model).

Table 1 Engine specification of calculation model

Displacement [cc]……………………..	1132
Bore [mm] ………………………	112
Stroke [mm]…………………...……	115
Connecting rod length [mm]..…..…..	250
Compression ratio…………………..…	18.8
IVC [^{0}bTDC]……………………….	132
EVO[^{0}bTDC]…………………..… …	132

Table 1 shows the calculated engine specifications. In this study was used elementary reaction which is of natural gas. It includes 6 elements, 289 species and 1580 reactions.

2.1 Fuel

Natural gas is a challenging fuel for HCCI engines because its single-stage ignition and rapid combustion make it difficult to optimize combustion timing over a significant load range. It consists of CH_4 87.61%, C_2H_6 6.33%, C_3H_8 4.09%, iC_4H_{10} 0.98% and nC_4H_{10} 0.98%.

2.2 Definition of minimum required initial temperature

All of simulation was considering on the closed portion of engine cycle. Which means calculation was from intake valve close (IVC) to exhaust valve close (EVC).

In the results of minimum required initial temperature, there are necessary for complete combustion (99.9%) [97p].

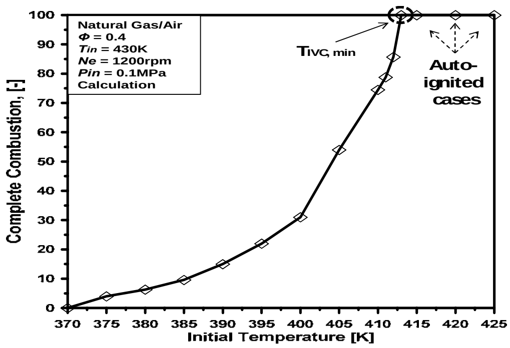

Fig. 1 Determine $T_{IVC,min}$ by complete combustion

2.3 Determination of autoignition

In appendix 1 shows the minimum required initial temperatures at the IVC and H_2O_2 mole fractions plotted with in-cylinder temperature at the (NA=0.1MPa). In this study, natural gas was selected as a fuel. Natural gas is a single stage ignition fuel. So, there is just one ignition stage which is HTHR. The start of HTHR (or start of TI prep range) was defined by radical of H_2O_2 increase slowly as the cycle processes, and peak near the point where the autoignition occurs [7]. Therefore, end of TI prep range (start of TI range) was defined by cross point of reaction rate of reaction R1 and R9 [1].

3. RESULTS

3.1 Minimum required initial temperature at the IVC

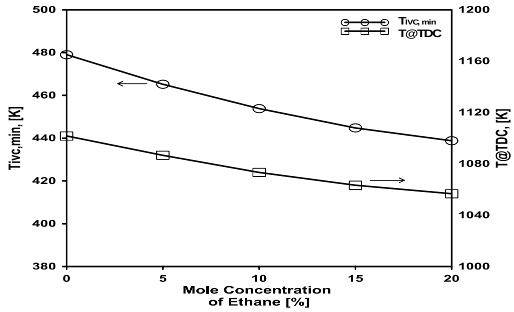

Fig. 2 $T_{IVC,min}$ and T_{TDC} as a function of ethane

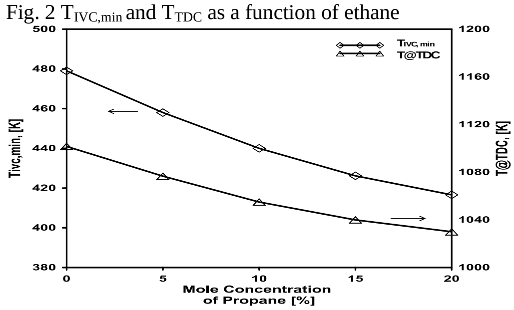

Fig. 3 $T_{IVC,min}$ and T_{TDC} as a function of propane

Fig 2-3 shows the minimum required initial temperature at IVC ($T_{IVC,min}$) and in-cylinder temperature at TDC plotted with respect mole concentration of ethane, propane, which were varied from 0 to 20%. When mole concentration of fuel species increased minimum required initial temperatures were slightly degreased.

4. CONCLUSION

We clarified the minimum required initial temperature at IVC for complete combustion on HCCI engine fueled with natural gas. There are two factors are affecting the $T_{IVC,min}$ for autoignition occur. 1) the change in ratio of specific heats (ɣ), 2) change autoignition threshold. From here, equivalence ratio, EGR ratio and boost pressures are affected much.

References

[1] Hiromitsu Ando, Yasuyuki Sakai and Kazunari Kuwahara, "Universal Rule of Hydrocarbon Oxidation", SAE (2009) 2009-01-0948

[2] Kazunari Kuwahara, Takuya Tada, Masahiro Furutani, Yasuyuki Sakai and Hiromitsu Ando "Chemical Kinetics Study on Two-Stage Main Heat Release in Ignition Process of highly Diluted Mixtures", SAE (2013) 2013-01-1657

[3] Kazunari Kuwahara and Hiromitsu Ando, "Role of Heat Accumulation by Reaction Loop Initiated by H2O2 Decomposition for Thermal Ignition" SAE (2007) 2007-01-0908