International Journal of Automotive Technology, Vol. 2, No. 3, pp. 93−101 (2001)

1229−9138/2001/005−02

ANALYSIS OF IN-CYLINDER FUEL−AIR MIXTURE DISTRIBUTION IN A HEAVY DUTY CNG ENGINE

SEOK Y. LEE[1)], KANG Y. HUH[1)*], Y. M. KIM[2)] and J. H. LEE[2)]

[1)]Mechanical Engineering Department, Pohang University of Science and Technology
[2)]Engine R&D Group, Korea Institute of Machinery and Materials

(Received 17 February 2001)

ABSTRACT−Distribution of fuel-air mixture has a strong influence on performance and emissions of a compressed natural gas (CNG) engine. In this paper, parametric study is performed by KIVA-3V to investigate fuel-air mixture with respect to injection timing, cycle equivalence ratio and engine speed. With open-valve injection intensive mixing during intake and compression stroke results in relatively homogeneous mixture in the cylinder. Sequential induction of fuel-air mixture and fresh air results in stratification in the cylinder among the test cases at closed-valve injection. There is close similarity in the calculated distributions of the mixture in the cylinder with different cycle equivalence ratios and engine speeds. The results are compared against pressure traces and flame images obtained in a single cylinder engine converted from a 11L six-cylinder heavy duty diesel engine.

KEY WORDS : CNG engine, Injection timing, Engine speed, Equivalence ratio

NOMENCLATURE

ϕ_i : local equivalence ratio
ϕ_m : mean equivalence ratio
ϕ_c : cycle equivalence ratio
σ : standard deviation
γ : specific heat ratio
P_e : nozzle exit pressure
T_e : nozzle exit temperature
ρ_e : nozzle exit density
V_i : volume of a computational cell
P_0 : stagnation pressure
T_0 : stagnation temperature

1. INTRODUCTION

Due to atmospheric pollution and limited oil reserve many fuels such as natural gas, LPG, hydrogen, alcohol, etc. have been considered as promising alternatives for urban transportation. Among them natural gas has a few advantages over other fuels for its lower cost, knocking resistance, and lower level of harmful emissions. Since natural gas has a higher octane number than gasoline, the compression ratio can be raised (Ishii, 1999) to achieve a higher efficiency with a lower rate of fuel consumption. Natural gas engines, however, have lower power and torque than gasoline engines due to lower volumetric efficiency and delayed ignition timing.

There have been recent efforts to overcome these shortcomings of a natural gas engine. Clark *et al.* (1998) reported very low levels of CO and NOx from natural gas vehicles through long term comparison with heavy duty fleet emissions. Hiltner *et al.* (1996, 1997) investigated the impact of the injection timing on in-cylinder fuel distribution in a natural gas engine. They showed in their experimental results that the best injection timing was 60 deg. ATDC in the intake stroke. Arcoumanis *et al.* (1997) investigated the combustion characteristics of gasoline and CNG engines using flame images, pressure traces and exhaust emissions from a single cylinder optical engine. It was shown that the fuel injection timing had significant effects on flame propagation and engine performances such as cyclic variation, IMEP and exhaust emissions.

Of crucial importance for natural gas powered engines is homogeneity of in-cylinder fuel-air mixture at the spark timing. The fuel-air mixture from liquid fuel is largely dependent on atomization and evaporation of the injected fuel droplets, while gaseous injection does not involve the complex phenomena. Mixing of gaseous fuel with ambient air is usually slower than that of liquid fuel due to the lower mass and momentum (Abraham *et al.*, 1994). The mixture formation process in a CNG engine is influenced by several factors such as fuel composition

**Corresponding author.* e-mail: huh@postech.ac.kr