Proceedings of Malaysian International Tribology Conference 2015, pp. 183-184, November 2015

Dynamic behavior of diesel spray during end-of-injection influence by ambient density and pressure fuel injection

Mohd Al-Hafiz Mohd Nawi*, Naoya Uwa, Yuki Ueda, Yuzuru Nada, Yoshiyuki Kidoguchi

Department of Mechanical Engineering, Institute of Technology and Science, Faculty of Engineering, The University of Tokushima, 2-1 Minamijyosanjima-cho, Tokushima 770-8506, Japan.

*Corresponding e-mail: alhafiznawi@gmail.com

Keywords: Diesel spray; droplets evaporation; end-of-injection

ABSTRACT – The implementation of high boost pressure, exhaust gas recirculation (EGR), and fuel injection pressure to diesel engines will improve the performance of fuel efficiency and reduce exhaust emissions. Hence, the present study is conducted at a different parameter of injection pressure and ambient density into the spray chamber. A dual nano-spark shadowgraph method and rapid compression machine (RCM) has been carried out to simulate real diesel engine to further understand the dynamic behavior of atomization, evaporation and droplets size distribution at the spray boundary. Data was obtained at the timing of quasi-steady state at 2.1ms after end-of-injection (aEOI). Based on this analysis, the structure of diesel spray has improved the atomization and droplets distribution of non-evaporating spray after end-of-injection (aEOI) onwards and it will lead an efficient diesel combustion and emission formation. Furthermore, the liquid phase penetration of evaporating spray is hardly affected by ambient atmosphere and pressure fuel injection.

1. INTRODUCTION

Recently, applying high supercharging, exhaust gas recirculation (EGR) and high-pressure injection will improve the engine performance. Furthermore, study on fuel spray is necessary to achieve high efficiency engine combustion. Therefore, some publications [1-2] reported that the effect of high ambient density will change the resistance of the atmosphere inside the spray chamber and affect the structure of diesel sprays and droplet evaporation. Previous studies [2-3] stated that the characteristics of penetration such as time and length depend on ambient density. By applying high pressure injection it will improve the atomization and mixture formation of spray evaporation. In the other hand, understanding the dynamic behavior and the mixture formation process of fuel spray, signifies a large effect on the exhaust emission and combustion ignition. According to this issue, the present study focuses on atomization at the spray centre, droplets size distribution and spray evaporation due to the effect of fuel pressure injection and atmospheric density of diesel spray after end-of-injection [4-5] conditions were investigated.

2. METHODOLOGY

Figure 1 and Fig 2 shows a schematic diagram of the experimental setup consisting of a spray chamber, a rapid compression machine, fuel injection device and a nano-spark photography unit. The experiment uses a single-hole injector with a hole-diameter of 0.18mm at an orientation of 15° from injector axis. The fuel of JIS#2 diesel fuel is used in this study. Here, the injection period is fixed at 2.0ms. The spray chamber is 60mm in diameter and 20mm in width is filled with inactive gases to enable the capturing of the spray image without burning. In the rapid compression machine (RCM) device, high pressure nitrogen gas in the cylinder rapidly compresses and drives the aluminum piston of 50mm diameter to the spray chamber, this is to imitate the temperature and pressure field of a condition inside a real diesel engine.

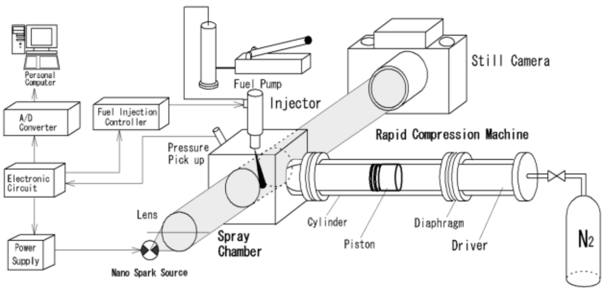

Figure 1 Experimental setup of single nano-spark shadowgraphy photography method.

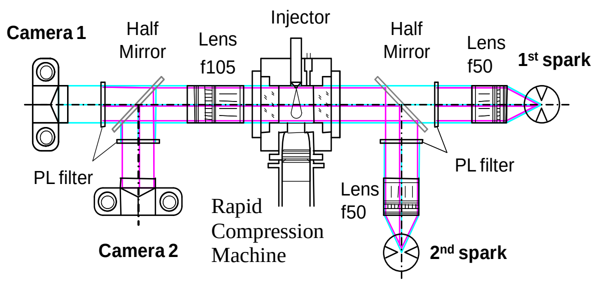

Figure 2 Optical arrangement of dual nano-spark shadowgraphy method.

Furthermore, as shown in Fig 2, a short high intensity light of 30ns duration have send towards spray imaging. Here, two images of different short time intervals are being captured. These images are used to study the droplets formation, atomization and evaporation at the spray boundary. Ambient density at ρ_a=15kg/m^3 to 35kg/m^3 and ambient temperature of T_i=298K are changed as experimental parameters. The injection pressure is adjusted from 60MPa to 100MPa.

3. RESULTS AND DISCUSSION

3.1 *Effect of Fuel Injection Pressure and Ambient Density of Spray Evaporation*

Figure 3 shows the comparison of the spray image with the condition of Ti=298K under room temperature and the density of the atmosphere increases from ρ_a=15kg/m^3 to 25kg/m^3. The image is captured after start of injection 2.1ms aSOI. In this condition, the spray has already transformed from non-evaporating to evaporating spray at the entire spray region. The shape and tip of the spray are still the same although they are in a different ambient density condition. This is contrary to the early injection condition. Furthermore, the tip of the spray has loses its initial momentum due to no fuel supply and the interaction between fuel and air is quite weak as previous study [4]. Compared to the early injection, the density or core inside the spray region is still difficult to expand and atomize. However, at the aEOI condition, the atomization in the spray centre has improved. This is cause by air motion inside the spray chamber that is entrained into fuel spray. By imposing high pressure fuel injection, a lot of atomization and droplets are produced during spray evaporation. This is due to the air surface has a low shear stress and friction after end of injection (aEOI).

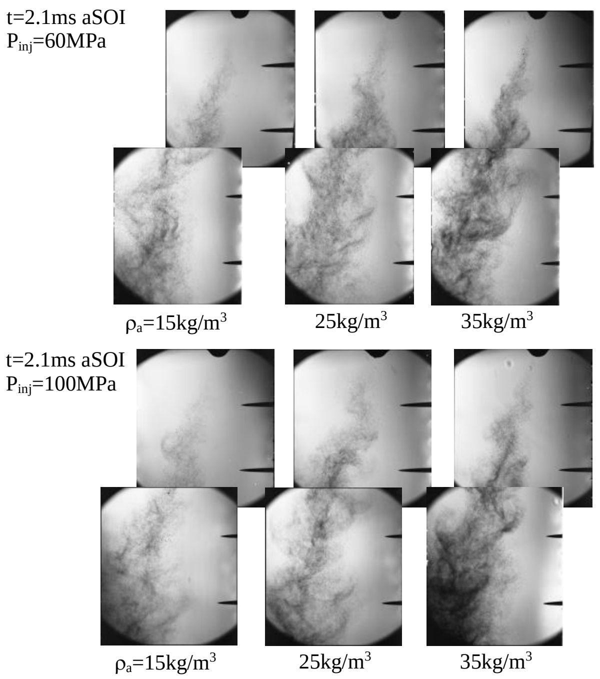

Figure 3 Effect of fuel pressure injection on macro-scale spray structure at spray boundary (T_i=298K).

3.2 *Dynamic Behavior of Droplets Distribution*

Figure 4 shows the number of droplets N, against the diameter, D of 5μm of each particle size of the droplets under T_i=298K. This figure clearly shows that smaller droplets are hard to spread out during initial stage due to high density atmosphere. Furthermore, droplet size distribution is formed at the upper and middle spray boundary especially at the spray center. This means that the liquid fuel shows much better spray atomization when the time increases.

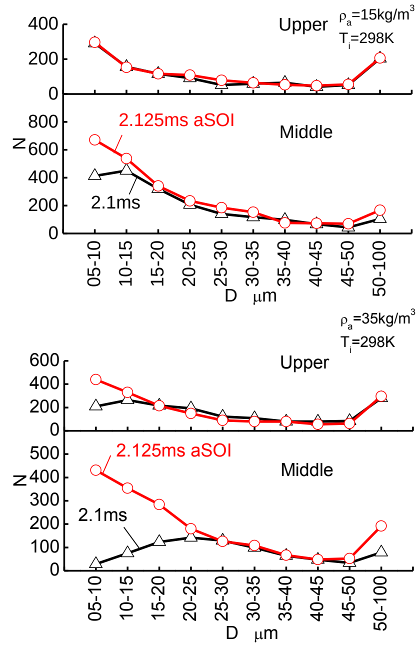

Figure 4 Change in droplets size distribution at spray boundary (T_i=298K, P_{inj}=60MPa).

4. CONCLUSION

By comparing the condition after end-of-injection (aEOI) and after start of injection (aSOI), the atomization increases as the time increases at the upper and middle stream of spray boundary. Looking at the atomization and evaporation of droplet size distribution, the analysis shows a lot of droplets are formed at after end-of-injection (aEOI). This is because the air entrainment affects the evaporation of the spray especially in the spray centre eventhough under high ambient density condition.

5. REFERENCES

[1] I.V. Roisman, L. Araneo, and C. Tropea, "Effect of ambient pressure on penetration of a diesel spray," *International Journal of Multiphase Flow 33*, pp. 904-920, 2007.

[2] J. Naber, and D. Siebers, "Effects of Gas Density and Vaporization on Penetration and Dispersion of Diesel Sprays," *SAE Technical Paper*, No. 960034, 1996.

[3] C. Arcoumanis, M. Gavaises, and B. French, "Effect of Fuel Injection Processes on the Structure of Diesel Sprays," *SAE Technical Paper*, No. 970799, 1997.

[4] S. Moon, Y. Matsumoto, and K. Nishida, "Entrainment, Evaporation and Mixing Characteristics of Diesel Sprays around End-of-Injection," *SAE Technical Paper*, No. 2009-01-0849, 2009

[5] S. Kook, L. Pickett, and M. Musculus, "Influence of Diesel Injection Parameters on End-of-Injection Liquid Length Recession," *SAE Int. J. Engines*, No. 2009-01-1356, 2009.