EFFECT OF AMBIENT CONDITIONS ON SPRAY CHARACTERISTICS OF DME FUEL

Hyun Kyu Suh 1, Sung Wook Park 2, Mun Soo Chon 3 and Chang Sik Lee 4,*

1 Graduate School of Hanyang University, hksuh@ihanyang.ac.kr
2 Graduate School of Hanyang University, swpark@ihanyang.ac.kr
3 Department of energy system Engineering, Chungju National University, mschon@chungju.ac.kr
4 Department of Mechanical Engineering, Hanyang University, cslee@hanyang.ac.kr

ABSTRACT This study was conducted to investigate the effect of ambient conditions on the spray characteristics of DME fuel injected from a common-rail injection system.

The spray characteristic of DME fuel was analyzed in terms of spray tip penetration, spray cone angle, impingement timing and centroid of spray. For the illuminated of spray, the spray visualization system was composed of a Nd:YAG laser and an ICCD camera and laser-sheet method was used. A high pressure chamber with optical window was used to allow the simultaneous observation of the effect of ambient conditions on the spray characteristics of DME fuel. The experiments are conducted in variable injection, ambient, temperature and combustion geometry conditions.

It is revealed that DME fuel shows a shorter spray path penetration, wider spray cone angle and much quicker evaporating process than diesel fuel. The spray area of DME is increased with increase of ambient temperature and centroid of spray is move to the downstream of spray development. In the case of non-evaporating spray characteristics, the spray development of DME is slower and rapidly disappeared as elapsed time after start of injection at the same injection duration. The impingement timing of diesel fuel was faster than that of DME fuel.

Keywords : common-rail injection system, spray development, spray tip penetration, spray cone angle, spray area

1. INTRODUCTION

The characteristics of fuel spray and mixture formation have greatly effects on the combustion process in direct injection diesel engine. From the reason of this, in diesel engine, fuel injection system was developed with atomization and evaporation of fuel droplets. However, exhaust emissions such as P.M. and NOx which was generated from diesel engine induce serious environmental problems. Therefore, the researches of clean and low emission engines to satisfy strict environmental regulations were necessary.

Recently, DME fuel is considered as alternative fuel to solve the exhaust emissions such as NOx and P.M. emissions in diesel fuel. The spray and evaporating characteristics of DME is very important for improvement of higher efficiency and reduction of emissions. In this point of views, there are many researches to analyze the characteristics of DME spray and combustion.

Kim et al. [1] analyzed the combustion characteristics of DME such as combustion pressure, combustion duration and pollutant as compared with LPG in a constant volume chamber. No et al. [2] studied the DME spray characteristics such as spray tip penetration, spray angle and SMD in various injection conditions. Yosho et al. [3] investigated the spray characteristics and evaporating processes of DME using the optical system. They reported that the spray tip penetrating speed of DME was slower and spray angle was wider than that of diesel because the breakup time of DME is shorter and the evaporation process of DME is quicker than that of diesel. They also conducted the experimental investigation to clarify the effect of DME injection characteristics on heat release and exhaust emissions[4,5]. DME spray characteristics compared to diesel injected through common-rail injection system was studied by Yu et al[6] . They visualized DME spray development and compared with the spray tip penetration and spray angle of diesel. Ikeda et al. [7] measured the injection rate of multiple injections on common-rail injection system between diesel and DME.

Many other researches [8-10] have reported on spray characteristics of DME based on the experimental and theoretical studies. However, the investigation about the effect of ambient conditions on DME fuel spray is still needed.

Combustion in a diesel engine is closely related to the fuel spray into combustion chamber at high pressure and temperature conditions. So, in order to obtain the maximum benefits from the use of DME fuel, it will be necessary that a better understanding about spray and combustion characteristics of DME fuel. For the improvement of fuel economy and exhaust emissions, a better understanding of the fuel spray behavior, mixture formation, and combustion characteristics in the cylinder is necessary so that the fuel supply control and the component characteristics can be optimized.

In spite of many previous experimental and theoretical researches of DME fuel, detail information about the spray behaviors of DME is still limited and has many uncertainties due to the difficulties of conducting experiments in an in-cylinder spray behavior.

This study was conducted to analyze the effect of ambient conditions on spray characteristics of DME fuel injected through a common-rail injection system. In order to investigate the effect of ambient conditions on macroscopic spray characteristics of DME, the experiments are conducted in variable pressure, ambient, temperature and combustion geometry conditions.
2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 Experimental Apparatus

This work was performed to analyze the effect of ambient condition such as injection pressure, ambient pressure, ambient temperature and combustion chamber geometry on spray development of DME fuel. Figure 1 shows the schematics of spray visualization system to get the spray development images.

![Schematics of spray visualization system](Image)

Fig. 1 Schematics of spray visualization system

The macroscopic structure of the spray such as spray tip penetration and overall behavior can be obtained from the frozen images by using the spray visualization system. The visualization system is composed of a Nd:YAG laser (Continuum, SL2-10), cylindrical lenses and mirrors, a digital delay/pulse generator, an ICCD camera (Stanford Computer optics, 4 Quick 05A), and a PC installed an image grabber. As a light source, the Nd:YAG laser which has the 532nm of wave length was used. Cylindrical lenses which form a laser sheet beam less than 1mm was used in order to illuminate the spray. A high resolution ICCD camera is used to get the frozen image of the spray. A high-pressure injection system was made for an easier control of injection pressure in comparison to the conventional high-pressure pump for the common-rail injection system. In order to pressurize the common-rail for the injection of a spray, two high-pressure pumps (Haskel, HSF-300) that are operated by compressed air, generate a high-pressure of fuel and store it in a common-rail. The pressure regulator and the quantity of the inlet air control the pressure of common-rail up to 200MPa. The high-pressure chamber that can be pressurized up to 4MPa was used to generate the ambient pressure using the nitrogen gas. To maintain constant temperature in the high pressure chamber, the temperature regulator which can be measured temperature by thermocouple was installed. The DME was pressurized to 1MPa by nitrogen gas in fuel tank to avoid vaporization in the fuel supply line. The specifications of spray visualization system are shown in Table 1.

In order to describe and investigate the effect of ambient conditions on the spray behavior, the DME and diesel fuel was injected into high-pressure chamber. In this study, to analyze the spray development process in combustion chamber, different type of combustion chamber was used. Details of combustion chamber geometry are shown in Figure 2. Figure 2 (a) illustrates the conventional combustion chamber which has 135 degree for fuel injection and narrow angle combustion chamber has 74 degree of combustion chamber wall for fuel injection. The visualization area indicates as dot-square box in Figure 2.

![Schematics of combustion chamber geometry and visualization area](Image)

(a) Conventional combustion chamber for fuel injection
(b) Narrow angle combustion chamber for fuel injection

Fig. 2 Schematics of combustion chamber geometry and visualization area

<table>
<thead>
<tr>
<th>Specifications of spray visualization system</th>
<th>Light source</th>
<th>Nd:YAG laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave length</td>
<td>532nm</td>
<td></td>
</tr>
<tr>
<td>Laser power</td>
<td>270mJ(max)</td>
<td></td>
</tr>
<tr>
<td>Beam thickness</td>
<td>~1mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICCD camera</th>
<th>Pixel size</th>
<th>6.7μm×6.7μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan area</td>
<td>8.6mm×6.9mm</td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>1280(H)×1024(V)</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Experimental Procedure

Diesel fuel is injected at compression stroke in a DI diesel engine. So, in order to analyze the spray behaviors of in-combustion chamber conditions, in-cylinder conditions were calculated in terms of piston distance from nozzle tip to combustion chamber and ambient pressure. Among these data, two cases were used to decide the injection time. Figure 3 illustrates the distance from injector to piston upper surface and ambient pressure.

![Piston distance from nozzle tip to combustion chamber and ambient pressure](Image)

Fig. 3 Piston distance from nozzle tip to combustion chamber and ambient pressure

Table 1 Specifications of spray visualization system

- Injection timing
- In-cylinder pressure
- Distance from the wall
- Ambient pressure(MPa) vs Distance from the wall (mm)
- Crank angle degree(°)

- Injection timing
- In-cylinder pressure
- Distance from the wall