THE ATOMIZATION CHARACTERISTICS OF BIODIESEL

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Abstract – Biodiesel has large amount of oxygen in itself, which make it very efficient in reducing exhaust emission by improving combustion inside an engine. But biodiesel has a low temperature flow problem because it has a high viscosity. In this study, the spray behavior and atomization characteristics were investigated to confirm of some effect for the combination of non-esterification biodiesel and fuel additive WDP and IPA. The process of spray was visualized through the visualization system composed of a halogen lamp and high speed camera, and atomization characteristics were investigated through LDPA. When blending WDP and IPA with biodiesel, atomization and spray characteristics were improved. Through this experimental result, SMD of blended fuel, WDP 25% and biodiesel 75%, was 33.9% reduced at distance 6㎝ from a nozzle tip under injection pressure 30MPa.

Keywords – Atomization, Sauter mean diameter (SMD), High speed camera, Biodiesel

1. INTRODUCTION

Petroleum used as the main energy source of the internal combustion engine has exhaustion problems. Also, while the environmental pollution emerges as the global topic, the exhaust emission including the smoke, CO₂ from the diesel engine is recognized as a major cause of environmental pollution. In order to resolve that, research on reducing exhaust emission is ongoing, depending on injection timing, atomization, valve timing, high pressure injection et al. (e.g. [1]). In a diesel engine field, researches on biodiesel produced from biomass are ongoing as alternative fuel of petroleum. Biodiesel has an effect on combustion improvement in a combustion chamber and reductions of particulate matter (PM), CO₂, smoke at high load and high speed region of the engine because biodiesel contains oxygen itself. Choi et al. (e.g. [2]) used blended fuel of biodiesel 20% with diesel fuel 80% and operated a CRDI engine more than 150 hours. They resulted that engine components and lubricant oil were not changed, and smoke and CO₂ were decreased. The diesel engine injects fuel under high pressure and temperature, injected fuel is ignited. Thus, a spray behavior and atomization have influent on engine performances and exhaust emissions. Those are affected by fuel properties of density and viscosity, surface tension. (e.g. [3]) Spray behavior and atomization characteristics are different when using high viscosity biodiesel. (e.g. [4], [5]) If viscosity of fuel is high, kinetic energy of fuel is reduced due to friction loss of fuel inside engine is increased. So, a break up of droplet is affected when injected fuel atomized, an engine performance is reduced and CO, HC are increased because combustion efficiency is decreased. In order to settle high viscosity of fuel, studies that are blending fuel additive with biodiesel are ongoing. (e.g. [6], [7]) Also, production cost of esterification biodiesel is high nowadays. But, non-esterification biodiesel that will be tried to an experiment does not require treatment cost of the glycerin generated during the esterification as well as does not use methyl alcohol, which cost about 20% of the biodiesel product cost and, as a result, insures price competitiveness. Therefore, this research considered that non-esterification biodiesel settles the high product cost of esterification biodiesel. Thus this research had comparatively analyzed spray behavior depending on spray pressure and blended fuel, biodiesel (hereinafter called BD) and WDP (water dipole power), IPA (isopropyl alcohol), by using LDPA and high speed camera.
Ⅱ. EXPERIMENTAL APPARATUS AND METHODS

Fuel used in the experiment has been made of common diesel fuel and BD extracted from Palm oil. In a making process of BD, after charging a high voltage of 900 thousand volt to BD, it has been made by repeating a method which is rapidly freezing BD. Particularly, using methanol when producing BD is omitted, and because glycerin is not generated it is a kind of effective BD for net caloric value of fuel. Table 1 shows the properties of fuel used in this study. WDP (Water Dipole Power, TEMPER Co. JAPAN) blended with BD is fuel additive, which reduce viscosity of non-esterification biodiesel. The spray system to analyze spray atomization of BD is as shown in Fig. 1. Experimental equipments were composed of injectors and injector drive, fuel supply equipment, LDPA. Fuel, through a fuel filter from a fuel tank, was supplied to an injector nozzle by a high pressure fuel pump (Haskel pump, USA) that compresses fuel at area ratio 150:1 by using air pressure which is compressed by a compressor. In order to injection control, a injection drive TDA-3100A (TEMS, Korea) was used. Also, spray behavior was analyzed by using a LDPA (Laser diffraction particle size analyzer) of a KF-Vario model of Sympatec Company (German). LDPA consists of a transmitter with a receiver, and a source of light is HE-Ne laser of 632.8nm. Spray images were obtained by using high speed camera (Photron, Fastcam-ultrama40k) which takes a photograph 40,500 frame per second. High speed camera and injector drive were synchronized by digital delay pulse generator (DG535, USA).

Table 1 Properties of test fuels

<table>
<thead>
<tr>
<th>Item</th>
<th>Diesel</th>
<th>BD</th>
<th>IPA</th>
<th>WDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value, (MJ/kg)</td>
<td>43.96</td>
<td>34.81</td>
<td>15.63</td>
<td>16.6</td>
</tr>
<tr>
<td>Kinematic viscosity (cSt, 40°C)</td>
<td>2.61</td>
<td>8.09</td>
<td>1.00</td>
<td>1.01</td>
</tr>
<tr>
<td>Specific gravity (g/cm³)</td>
<td>0.83</td>
<td>0.90</td>
<td>0.78</td>
<td>0.79</td>
</tr>
<tr>
<td>Hydrogen (wt%)</td>
<td>13.82</td>
<td>12.40</td>
<td>14.12</td>
<td>13.31</td>
</tr>
<tr>
<td>Oxygen, (wt%)</td>
<td>-</td>
<td>11.60</td>
<td>25.64</td>
<td>26.62</td>
</tr>
</tbody>
</table>

In order to compare spray behavior of common diesel fuel and BD used in the experiment, has been blended into diesel fuel 100%, BD75%+WDP25% (hereinafter called WDP 25), BD100% (BD100) by changing blending ratio to volume. Also injection pressure has been changed from 30MPa to 60MPa every 10MPa and set up spray time at 4㎲ by using a TDA-3100A. Measured outputs from the experiment were a representative diameter of volume accumulation mass 10% and 50%, 90% and SMD (Sauter mean diameter). Span factor which is a relative distribution section index. Span factor, shown equation (1), indicated by using a volume accumulation distribution and is the most suitable index of output on LDPA.

\[ \text{Span Factor} = \frac{D_{90} - D_{10}}{D_{50}} \]  

Where:
- \(D_{10}\) = Droplet diameter at volume accumulative mass 10%
- \(D_{50}\) = Droplet diameter at volume accumulative mass 50%
- \(D_{90}\) = Droplet diameter at volume accumulative mass 90%

Ⅲ. RESULTS AND DISCUSSION

In order to analyze spray behavior of fuels, this research measured spray tip penetration and Sauter mean diameter, span factor depending on injection pressure and fuel by using the LDPA and visualization system.
Fig. 2 shows process of spray development versus fuel under each injection pressure after injection drive pulse. Time of injection start on every fuels were faster as the injection pressure is increased, also time of spray development was shorter. Spray development of BD 100 was slowest, it was sprayed in hardly broken up condition under 30MPa. Also, spray angle of diesel fuel in all injection pressure was wide and atomization was well made. Time of spray start, development of WDP25 and IPA 25 was shorter than BD 100 under every injection pressure and time of spray development on WDP 25 was slightly shorter than that of IPA 25.

This is thought that spray behavior was improved due to influence of reduced viscosity by fuel additive WDP.

Fig. 3 shows spray tip penetration of fuel under each injection pressure versus time of a drive signal. Spray tip penetration of every fuel was linearly increased as each injection pressure, and an increase in spray tip penetration of diesel fuel was fastest under every injection pressure. Spray tip penetration of WDP 25 and IPA 25 was similar, but time of spray start and development of WDP 25 were faster than these of IPA 25 under every injection pressures. And, it can be seen spray tip penetration of diesel fuel is lower than WDP 25 from 1400μm of time after start of injection under 30MPa. This is considered because atomization of diesel fuel is promoted due to low viscosity under low injection pressure, and the kinetic energy is reduced due to spray velocity reduction due to the influence of drag of ambient air. (e.g. [8], [9])
Fig. 3 Effect of fuel on spray tip penetration

Fig. 4 shows dispersion degree (span factor) of spray size distribution at a 6cm distance from nozzle tip downstream. Low value of span factor means that deviation of spray size distribution from mean diameter is small and spray size is distributed in a narrow range. Span factor of diesel fuel was few increased as injection pressure was increased, because the ratio of the small droplet while large droplets are broken up is increased due to the relative speed increase between ambient air and spray, the kinetic energy increase. Span factor of BD 100 was definitely different and irregular under 30MPa, because droplet of BD 100 was rarely atomized and widely distributed due to influence of high viscosity under low injection pressure. WDP 25 was rarely influenced of injection pressure, and droplet of which deviation with mean diameter is small was distributed in a narrow range.

(e.g. [10])

Fig. 5 shows dispersion degree (span factor) of spray size distribution at 10 cm distance from nozzle tip downstream. This point is downstream of spray; therefore, atomization of diesel fuel and WDP 25 were almost completed. Hence, those are influenced to increase injection pressure, and similar size droplets were distributed.

Fig. 6 shows Sauter mean diameter (SMD) at a 6cm and every fuel were reduced depending on an increase in injection pressure, this is thought that droplet size was reduced because of atomization is promoted while injection pressure increase. When comparing WDP 25 with IPA 25, droplet of those fuels is overall similar, droplet size of WDP 25 is slightly smaller at 6cm. SMD at a distance 10cm from nozzle tip was overall larger than a 6cm distance, this is considered that droplets cohore of influence in reduced spray tip penetration as a distance from nozzle tip become more distant. (e.g. [10])
IV. CONCLUSION

In order to analyze spray behavior of BD, study on fuel spray experiments that have been conducted while changing injection pressure and blending ratio of BD and common diesel fuel has given following conclusions.

(a) The time of every fuel spray development was shorter depending on an increase in injection pressure, and the time of spray start and development of WDP 25 was faster than BD100.

(b) Span factor value of WDP 25 was lower than that of BD. This is considered that the droplet of WDP 25 is distributed in a narrow range of influence in viscosity reduction.

(c) When injection pressure was increased, SMD of WDP 25 was reduced. Also, SMD of WDP25 was generally smaller than that of BD. Thus, this research considers that BD in the case of blending WDP was able to apply the high pressure injection type engine.

V. REFERENCES


