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THE INFLUENCE OF INJECTION PRESSURE AGAINST MIST CHARACTERISTICS OF DIESEL–DME MIXTURES FUEL IN THE ENGINE

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ABSTRACT

Fuel mist injection plays a main role in determining the performance of diesel engines, where the mist pattern illustrates fuel combustion occurs in the combustion chamber. Characteristics of Sauter Mean Diameter (SMD) mist is devoted to fuel evaporation, and mixing and combustion quality affected by pressure injection (ΔP) and the physical chemical properties of the fuel (density, surface tension, viscosity and boiling point). From fuel spray test results showed that fuel evaporation characteristics of fuel at a certain pressure effect on engine performance. The higher the injection pressure will reduce the diameter of the fuel mist after injection (SMD), thus speeding up evaporation and mixing processes between fuel and air in the combustion chamber with resulted the combustion process is more completely.

Keywords ***: Diesel-mix-DME fuel, injection pressure, engine combustion chamber***

1. INTRODUCTION

Development efforts alternative fuels as a substitute for fuel oil become increasingly stronger demands, where the consideration for the making of new alternative fuels that have an impact on society, such as the impact of greenhouse gases, the amount of reserves, availability, convenience and compatibility the transport sector and other sectors use, infrastructure, economical, and safe [5].

Di-methyl ether (DME) is the simplest ether compound with the chemical formula CH3OCH3 known as organic solvent extraction and the media in the form of a colorless liquid aerosol propellant for industrial use. DME as a propellant widely used as one of the driving ingredient in the perfume industry, medicine mosquito repellent, personal care (hair spray, foams, shaving cream, antiperspirants), colognes, room air fresheners, food coolants, industrial coating, paints and finishing as well as automotive.

At ambient temperature and atmospheric pressure conditions is colorless gaseous which has properties resembling propane (C_3H_8) and LPG. Whereas at ambient temperature conditions with 6 atm pressure or at atmospheric pressure with a temperature of -25ºC form a colorless liquid that can be transported and stored in tanks at low temperatures such as LPG [4].

DME is highly flammable, without causing soot under any circumstances because the oxygen atoms contained in the molecule. DME is also a non–toxic chemicals or compounds that do not contain sulfur (S) and nitrogen (N) so that emissions (SOx NOx, particulates and soot) are much lower than diesel (diesel) and do not damage the ozone layer. In addition, DME is not corrosive to metals that do not require special modifications to the existing infrastructure of LPG when used as a replacement or LPG mixer.

At low mole fraction (% volume low), this gas has a very strong scent and even though a high mole fraction (> 10% volume) has no effect on health, except the effects of inhaling the drug after long periods of time, but even then can be recognized by the odor.

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DME has a lower calorific value than LPG or LNG or ± 65% of natural gas (CH_4) or ± 40% of MeOH, due to differences in chemical structure, but the density of liquid DME larger so that the total heating value of a tank DME ± 90% of the tank similar to LPG. Cetane Number (CN) high DME (55 ~ 60) is a measure of the combustion quality of diesel fuel during compression ignition, so it can be used as a substitute for diesel fuel [2].

DME is currently being projected as a source of environmentally friendly alternative fuel, which can be produced from syngas various sources of energy, such as coal, biomass and natural gas. Syngas can be produced through gasification of coal / biomass or partial oxidation / steam methane reforming / auto-thermal reforming of natural gas. DME-making process there are two ways the process directly (direct process) and indirect processes (indirect process). Direct process is a process of formation of syngas ($CO + H_2$) which can be produced through gasification of coal / biomass or natural gas partial oxidation process, then synthesized into DME. While the indirect process is a process that begins with the manufacture of MeOH, followed by MeOH dehydration in a separate reactor synthesized into DME.

DME utilization means has increased economic value and as an effort to reduce dependence on oil as well as solving the problem of environmental pollution. Viewed from the comparison of fuel prices, DME is still competitive compared to LPG and diesel fuel. On the basis of energy equivalence, DME production cost is lower than diesel. However, the difference in characteristics between diesel and DME led to the use of DME as a fuel in diesel engine injection systems require modification of existing ones. DME combustion was not issued because it contains oxygen and soot structure without forming chemical bonds of carbon.

The advantages of DME shows the potential to be an alternative fuel in diesel engines, while the shortcomings to be applied is a challenge that must be answered through research.

2. LITERATURE REVIEW

In general, the combustion characteristics are influenced by two important parameters, namely: injection pressure (ΔP) and physical chemical properties of the fuel (density, surface tension, viscosity and boiling point). At the beginning of the injection ($t_{asoi} \le t_b$), or long distance mist penetration (S) is influenced by pressure injection (ΔP) and fuel density (ρ_l), as defined by equation [1].

$$t_{asoi} \le t_b : S = 0.39 \sqrt{\left(\frac{2\,\Delta P}{\rho_l}\right)} t_{asoi} \qquad [1]$$

Equation [2] shows the empirical formula for long-distance or mist penetration (S) after the injection process is complete ($t_{asoi} \ge t_b$), where the influence of injection pressure and physical chemical properties of the fuel decreases even none at all, while the influence of the density of the air around the enlarged.

$$t_{asoi} \ge t_b : S = 2.95 \left(\frac{\Delta P}{\rho_g}\right)^{0.25} \sqrt{D(t_{asoi})} \quad [2]$$

$$\text{di mana} : t_b = \frac{28.65\, \rho_l\, D}{\sqrt{\rho_g\, \Delta P}}$$

Mist characteristics of SMD (Sauter Mean Diameter) devoted to fuel evaporation, mixing and combustion quality, is also influenced by pressure injection (ΔP) and physical chemical properties of the fuel, as defined by equation [3].

$$SMD = 6156\, v_m^{0.385} \gamma_m^{0.737} \rho_m^{0.737} \rho_A^{0.06}\, \Delta P_L^{-0.54} \quad [3]$$

ρ_m : Density
ν_m : Viscosity
γ_m : Surface tension
ρ_A : Density ambient air
ΔP_L : Injection pressure of mist

Based on the results recorded images using a digital camera video shows the interaction or the influence of injection pressure and physical chemical properties of the fuel to the fuel mist characteristics.

3. RESEARCH

Fuel mist test of Diesel, DME and Diesel-mix-DME conducted at the Laboratory Institute of Technology Motor and Propolsi - PUSPIPTEK - Serpong.

3.1. Purpose

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To test fuel mist of Diesel, DME and Diesel-mix-DME on pressure variation for investigating the combustion characteristics in the engine.

3.2. Materials

Table 1 and Table 2 shows the fuel characteristics of DME and diesel oil respectively.

Table 1. Characteristic of DME

Physical Properties		DME
Chemical Formula		CH_3-O-CH_3
Molecular Weight	g/mol	46
C	% mass	52.2
H	%mass	13
O	% mass	34.8
Ratio C/H		0.337
Critical temperature	^oK	400
Critical pressure	MPa	5.37
Critical density	kg/m^3	259
Density of liquid	kg/m^3	667
Relative density of gas (air=1)		1.59
Cetane number		>55
Auto-ignition temperature	^oK	508
Stoichiometric air/fuel mass ratio		9.0
Boiling point at 1 atm	^oK	248.1
Enthalpy of evaporation	kJ/kg	467.13
Lower heating value (LHV)	MJ/kg	27.6
Specific heat capacity of gas	kJ/kgK	2.99
Ignition limits	%Vol air	3.4/18.6
Modulus of elasticity	N/m^2	6.37E+0.8
Kinematic viscosity of liquid	cSt	<1
Surface tension (298 K)	N/m	0.012
Vapour pressure (at 298 K)	kPa	530

Table 2. Characteristic of Diesel Oil

Physical Properties		Diesel Oil
Chemical Formula		-
Molecular Weight	g/mol	170
C	% mass	86
H	%mass	14
O	% mass	0
Ratio C/H		0.516
Critical temperature	^oK	708
Critical pressure	MPa	3.00[a]
Critical density	kg/m^3	-
Density of liquid	kg/m^3	831
Relative density of gas (air=1)		-
Cetane number		40-50
Auto-ignition temperature	^oK	523
Stoichiometric air/fuel mass ratio		14.6
Boiling point at 1 atm	^oK	450 – 463
Enthalpy of evaporation	kJ/kg	300
Lower heating value (LHV)	MJ/kg	42.5
Specific heat capacity of gas	kJ/kgK	1.7
Ignition limits	%Vol air	0.6/6.5
Modulus of elasticity	N/m^2	14.86E+08
Kinematic viscosity of liquid	cSt	3
Surface tension (at 298 K)	N/m	0.27
Vapour pressure (at 298 K)	kPa	<<10

3.3. Equipments

Figure 1 shows the mist test equipment for Diesel, DME, and Diesel-mix-DME, comprising:

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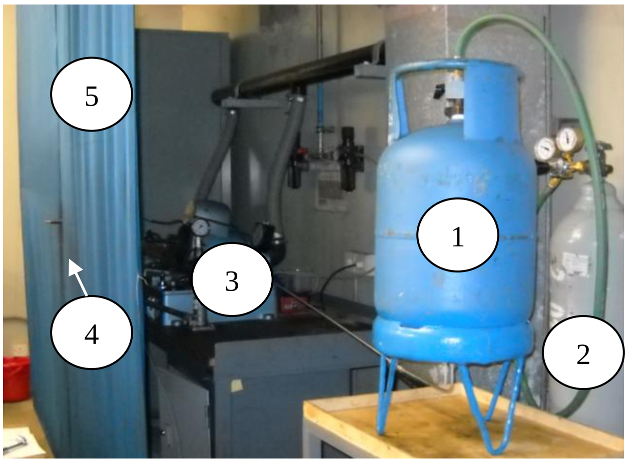


Figure 1. Mist test equipment for Diesel, DME, and Diesel-mix-DME

- The fuel tank (1) for storage (DME, diesel oil or diesel-mix-DME) derived from a modified LPG cylinder on the bottom that is made "legs" so that valves and napple under the tank as the fuel flow not oppressed.
- N2 gas tube (2) to give the fuel tank pressure above 5 bar (20ºC) so that the liquid phase DME can be perfecty mixed with diesel oil, and to keep the pressure of DME supplies into diesel injection tester remains high.
- Diesel injection tester (3) brand: Bosch, type: EFEP 60H, pressure: 40 MPa for testing mist fuel.
- *Diesel injector multi–hole* (5 holes) type *direct injection* (4) Isuzu Panther 2500cc with pressure max.18,5 MPa.
- Backgorund screen is made of blue fabric (5) in order to capture the fuel mist pattern as it exits the fuel injector by using a digital video camera can be seen clearly.

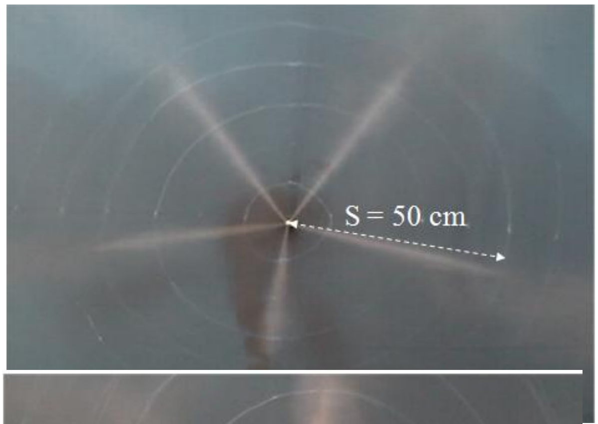
3.4. Metodology

- Install the nozzle opening pressure test equipment.
- Set the nozzle opening pressure on the pressure gauge by adjusting the injector spring contraction.
- Positioning the injector on the hole in the screen background..
- Pressing the pump lever downward to start testing..
- Take a photo or record a change in the pattern of images fuel mist using a digital video camera that can be clearly observed.
- After testing is complete, remove the tubing connector from the pump to the injector, and then empty the fuel in it to prepare for the next fuel mist testing.
- Repeat these steps for testing by variating of fuel and mist pressure.

4. RESULT AND DISCUSSION

4.1. Result

Figure 2, Figure 3, and Figure 4 respectively show the mist pattern Diesel 100, Diesel–mix-DME 50/50, and DME 100 at a pressure of 150 bar.



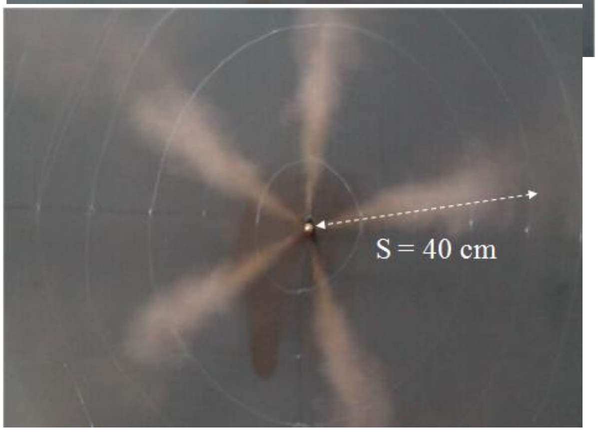


Figure 3. Mist pattern of Diesel-mix-DME 50/50 (150 bar)

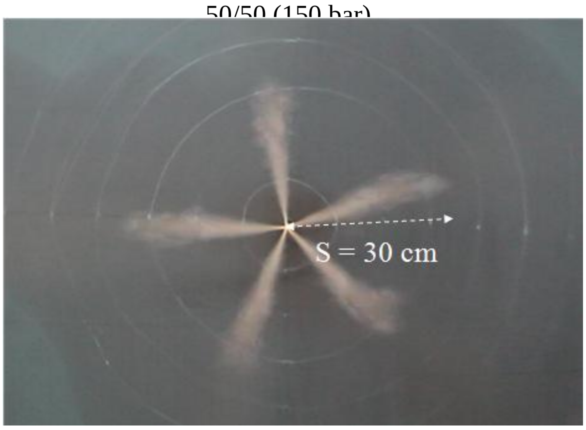


Figure 4. Mist pattern of DME 100 (150 bar)

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Figure 5, Figure 6, and Figure 7 respectively show the mist pattern of Diesel 100, diesel–mix-DME 50/50, and DME 100 at a pressure of 180 bar.

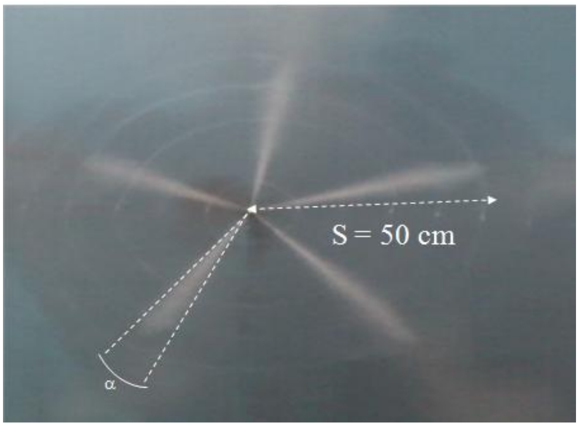

Figure 5. Mist pattern of Diesel 100 (180 bar)

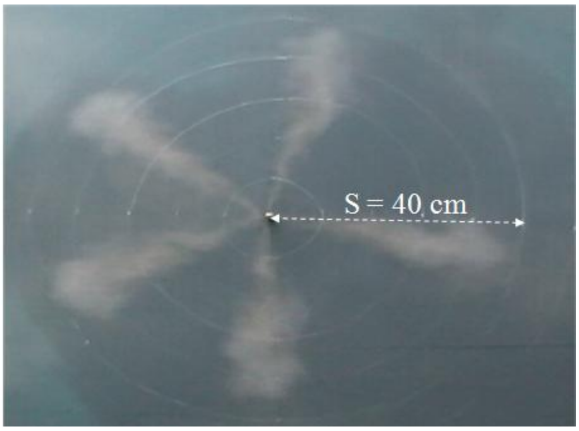

Figure 6. Mist pattern of Diesel-mix-DME 50/50 (180 bar)

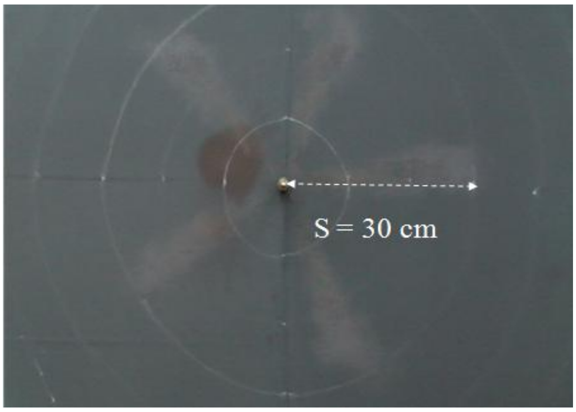

Figure 7. Mist pattern of DME 100 (180 bar)

Figure 8, Figure 9, and Figure 10 respectively show the mist pattern of Diesel 100, Diesel-mix-DME 50/50, and DME 100 at a pressure of 235 bar

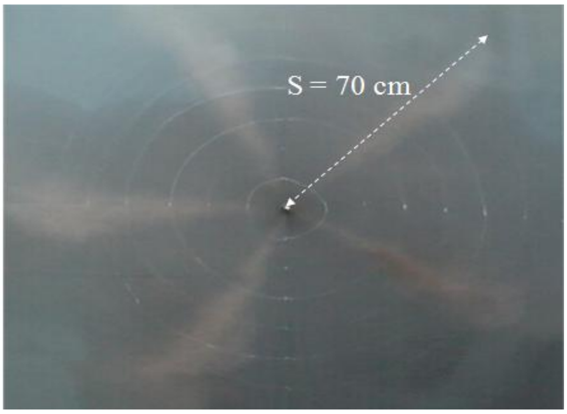

Figure 8. Mist pattern of Diesel 100 (235

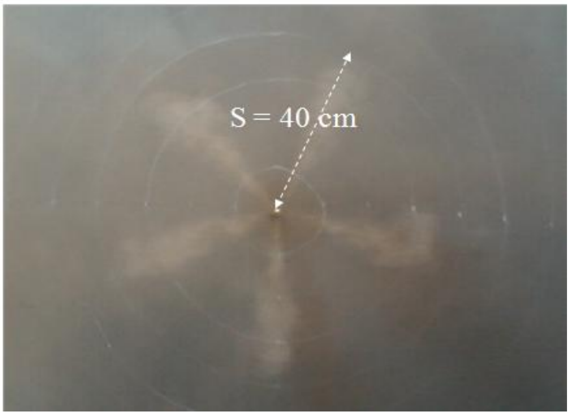

Figure 9. Mist patten of Diesel-mix-DME 50/50 (235 bar)

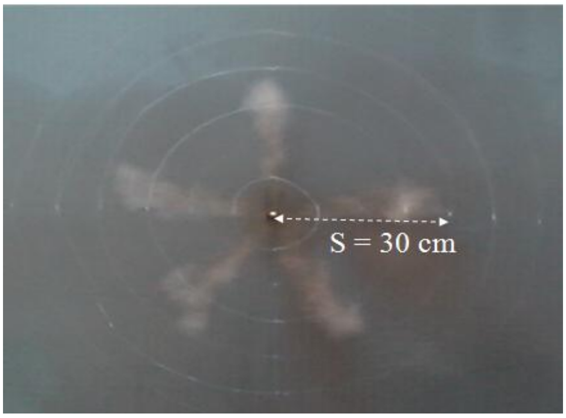

Figure 10. Mist pattern of DME 100 (235 bar)

4.2. Discussion

4.2.1. Fuel mist characteristics at an injection pressure of 150 bar

At an injection pressure of 150 bar, mist penetration distance (S) from Diesel 100 is the longest (50cm), while Diesel-mix-DME 50/50 around 40cm and DME 100 is the shortest (30cm). The differences mist penetration distance (S) is caused by the boiling point of DME (-25^{o}C, 1 atm) is much lower than diesel (150-380^{o}C, 1 atm), so DME is more volatile and tend to easily distributed sideways or going wide. Diesel granules with a higher boiling point will be more stable in a linear move in the direction injection pressure and tend to move straight, thus resulting mist penetration distance (S) is longer. Thus the higher content of DME, mist penetration distance (S) will be getting shorter.

Another tendency that arises is the higher content of DME in the wide angle solar mist formed; it is associated with the movement of steam molecules DME and diesel to the side. The higher DME content in the mix to make the process of mixing fuel and air is perfect so there will be more perfect combustion, it is caused by the formation of steam quicker and more at the start fogging [1].

4.2.2. Fuel mist characteristics at injection pressure of 180 bar

At higher injection pressure is about 180 bar, Kabutan penetration distance (S) is still relatively the same as the injection pressure of 150 bar. However, the injection pressure affects the grain diameter after fuel injected (SMD), especially at ambient conditions. The higher injection pressure will reduce the diameter of fuel droplets after injection to facilitate or accelerate evaporation. Figure 5 shows that the mist pattern of diesel 100 more spread indicated by fogging angle (α) is greater than the injection pressure of 150 bar in Figure 2. In Figure 6 and Figure 7 shows that the higher the content of DME is getting faster evaporation rates, as well as the greater angle fogging (α). Mixing process between the fuel and air in the combustion chamber, is getting better at a pressure of 180 bar compared to injection pressure of 150 bar.

4.2.3. Fuel mist characteristics at 235 bar pressure

At a pressure of 235 bar, fuel mist characteristics will change significantly their extent, this is because the grain diameter of diesel will become smaller, so that the rate of evaporation will be faster {3}. Mist penetration distance (S) on fuel fogging of Diesel 100 is still influenced by pressure injection (Figure 8), however, the influence of injection pressure was not significant on Diesel-mix-DME 50/50 (Figure 9) and DME 100 (Figure 10). Injection pressure will be more dominant effect on the incidence of mist (angle α*)* and the rate of fuel evaporation. The mixing and combustion processes between DME with air is getting better at a higher injection pressure.

5. CONCLUSIONS

Testing the mist characteristics of diesel, DME and blends in injection pressure variation of 150, 180 and 235 bar using Isuzu Panther Diesel car injector 2500cc direct injection type, it can be concluded that:

- The results showed footage of the interaction or the influence of injection pressure and physical chemical properties of the fuel against the fuel mist characteristics.
- At an injection pressure of 235 bar, mist penetration distance (S) Diesel 100 is the longest (70 cm), then the Diesel-mix-DME 50/50 approximately 40 cm and DME 100 is the shortest (30cm). While the mist penetration distance (S) of fuel at injection pressure of 150 bar and 180 bar, shows the same, ie 50 cm (Diesel100), 40 cm (Diesel-mix-DME 50/50), and 30 cm (DME 100).
- Differences mist penetration distance (S) due to the boiling point of DME (-25^{o}C, 1 atm) is much lower than Diesel (150-380^{o}C, 1 atm), so DME is more volatile and tend to be easily distributed to the side or going wide.
- The higher injection pressure will reduce the diameter of fuel droplets after injection (SMD) thus speeding evaporation and mixing process between the fuel and air in the combustion chamber.
- The higher content of DME mist penetration distance (S) will be getting shorter, faster evaporation rates, the greater the angle fogging (α), the mixing process fuel and air is perfect so there will be more perfect combustion, it is caused by the formation of vapor over quickly and more at the start fogging.

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