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The impact of methanol injecting position on cylinder-to-cylinder variation in a diesel methanol dual fuel engine

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HIGHLIGHTS

- The unevenness degree of engine reduces when ITd is retarded.
- COV_{IMEP} of each cylinder in different positions of methanol injected is analyzed.
- Impact of methanol injecting position on cylinder-to-cylinder variation is studied.
- The emissions of engine in different positions of methanol injected are analyzed.

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ABSTRACT

Methanol fumigation strategy in multi-cylinder diesel engine has received great attentions in recent years. Experimental work was conducted in a turbocharged inline 4-cylinder diesel engine fueled with diesel methanol dual fuel (DMDF). Three different methanol injection positions were chosen to investigate into their effect on cylinder-to-cylinder variation. The results indicate that the unevenness degree of each cylinder reduces as injection timing of diesel (ITd) retarded. The unevenness degree of engine is better when methanol injectors are fixed at intake manifold (Case 1) and at distal end of inlet duct (Case 2) than fixed at near end of inlet duct (Case 3). The cylinder-to-cylinder variation has a tendency to increase with an increase in methanol substitution percent (MSP). With the increasing engine load, the COV_{IMEP} of 4 cylinders reduces. In addition, the COV_{IMEP} rises with an increasing MSP under 50% and 75% engine loads, while it has no significant change under 100% engine load. The COV_{pmax} first increases and then decreases with the increase in engine load, and it has the maximum value under 75% engine load. Although there is a linear increase in the THC and CO emissions with the increase in MSP, the difference of THC and CO emissions between the three cases is very small under various engine loads. Under 50% and 75% engine loads, the soot emission in all three cases decreases slowly with the increase in MSP, and the difference of soot emission in three cases is small. Under 100% engine load, the soot emission in three cases first increases and then decreases with the increase in MSP, and the emission gaps fall apart further with the increase in MSP.

1. Introduction

Much work has been done on the use of alternative fuels in engine because of excessive depletion of oil resources and harmful emissions in conventional engines [1–3], especially in China where there is shortage of oil resources. Among those alternative fuels, the methanol, by-products of coal chemicals, is receiving great attention [4–6]. As a clean fuel, its productive resource is abundant.

The use of methanol fuel in gasoline engines is very popular because it can easily blend with gasoline fuel in any proportion [7]. In diesel engines, methanol fumigation methods have been

Abbreviations: MSP, methanol substitution percent; MIP, methanol injecting position; ECU, electronic control unit; DMDF, diesel methanol dual fuel; DMCC, diesel/methanol compound combustion; COV, coefficient of variation; IMEP, indicated mean effective pressure; AHRR, apparent heat release rate; ATDC, after top dead center; TDC, top dead center; SMD, Sauter Mean Diameter; CYL, cylinder; ITd, injection timing of diesel fuel; ESC, European steady state cycle.

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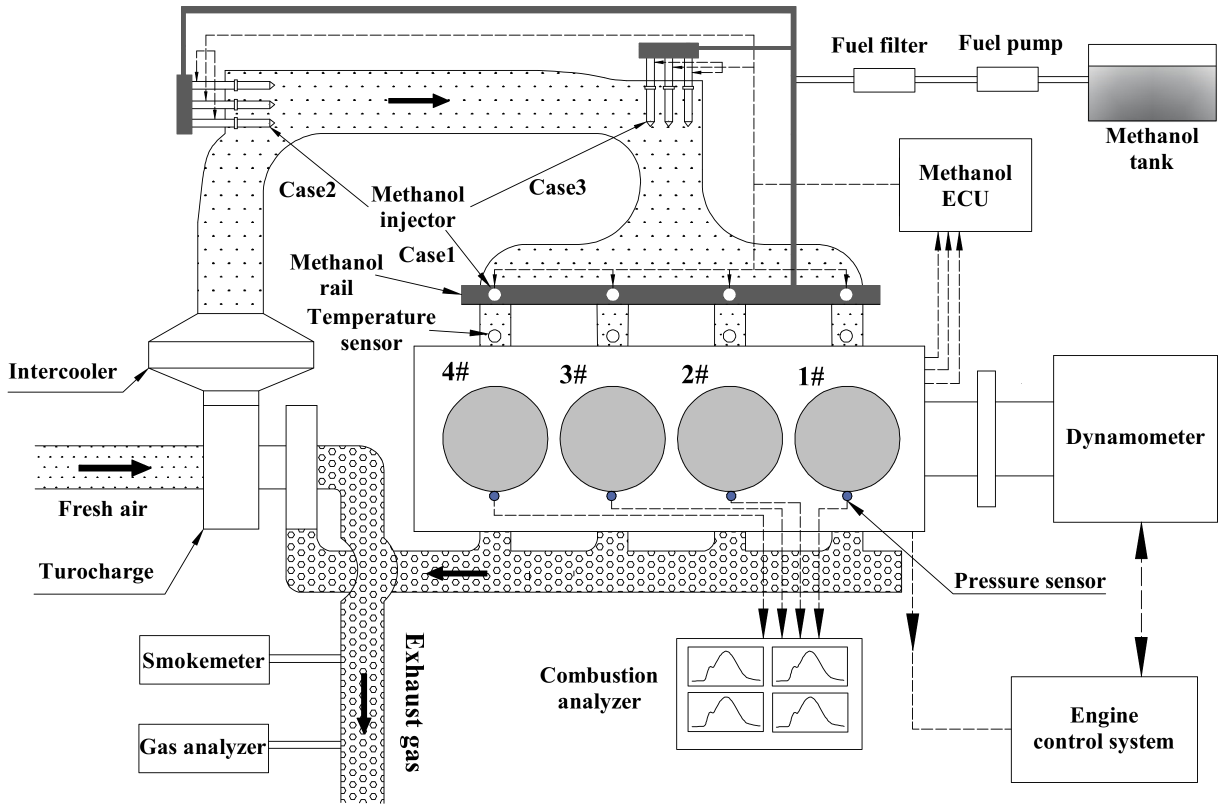

Fig. 1. Schematic diagram of experimental setup.

Table 1
Specifications of the test engine.

Item	Parameter
Type	4-cylinder, in-line, turbocharged, direct injection
Displacement (L)	4.2
Compression ratio	17.1
Bore × stroke (mm × mm)	108 × 115
Max. power (kW/(r/min))	103/1600
Max. torque (N m/(r/min))	420/1800

paid more and more attention [8]. In this way, methanol fuel is introduced into upstream of the manifold by spraying or carbureting [9,10], the maximum MSP can reach more than 70% under medium load condition [11–13], and the substitution ratio of methanol to diesel for the fumigation method is more flexible when engine load and speed change, and the engine can switch from dual fuel to diesel fuel only as demands [14]. Moreover, the standard and reliable assembly parts used in DMDF engine are able to be produced in mass.

High latent heat feature of methanol fuel reduces the ambient temperature in the intake duct and cylinder, and such phenomenon is more pronounced at high MSP [11,15]. It may cause cold starting problem of diesel engine, and the combustion in cylinder is unstable under low temperature which may lead to misfire of engine. The diesel/methanol compound combustion (DMCC) system developed by Yao et al. [16] can avoid this situation, it employs pure diesel mode under idle speed and low load, and the DMDF mode is used when engine load, cooling water temperature and speed reach certain values.

In DMDF engine, methanol fuel is injected into air inlet to form premixed mixture with air, and diesel fuel is directly injected into the cylinder. The premixed methanol and air mixture enters into each cylinder through a long pipe of air inlet, and then ignited by diesel fuel. Studies have found that the pulsating flow taking place in air inlet will affect the mass flow rate into each cylinder [17–20]. In the multi-cylinder diesel engine, the performance difference between each cylinder is very small because diesel fuel is injected directly into the cylinder, and diesel fuel is distributed equally among the cylinders. When partially substituted by methanol fuel, which is injected into air inlet to mix with air, the pulsating flow in air inlet will cause uneven distribution of methanol among the cylinders. Previous study on a side inlet duct and methanol fumigated diesel engine has found that the methanol quantity entered into 4 cylinders is different from each other, and the unevenness degree of engine rises with the increase in MSP [21].

The combustion difference between each cylinder is harmful to engine performance. In order to minimize the impact of pulsating flow on uneven distribution of methanol to each cylinder and fully understand the combustion condition in each cylinder, a turbocharged inline 4-cylinder diesel engine with air inlet middle

Table 2
Engine test combination.

Item	MIP	MSP (%)	Engine load (%)	ITd (°ATDC)	Temperature after inter-cooled (°C)	Engine speed (r/min)
Variation of ITd	Case 1	30	75	−11, −8, −5, −2, 1, 4, 7	50	1860
Variation of MIP	Case 1	0, 10, 20, 30	50, 75, 100	−5		
	Case 2					
	Case 3					