Effect of Diesel-Ethanol Blends as Fuels on Performance and Emissions of a Diesel Truck Engine

Nguyen Van Nhinh**, Pham Minh Tuan, Pham Huu Tuyen

Hanoi University of Science and Technology, No. 1, Dai Co Viet, Hai Ba Trung, Hanoi, Viet Nam

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Abstract

Recently, the alternative fuels have been widely researched and applied on internal combustion engine in many countries in all over the world because of fossil fuels limit and strict emission regulations. Among biofuels, ethanol is one of the most potential alternative fuels that is normally used for spark ignition engines and also possible for diesel engines. This paper presents an experimental research on performance and emissions of Hyundai D4BB 1.25 ton diesel engine truck using diesel-ethanol blends with different ratio of ethanol which are ED5 (95% diesel and 5% ethanol by voumel) and ED10 (90% diesel and 10% ethanol by volume) at full load. The results showed that there was a minor change in engine torque and fuel consumption, while HC and CO emissions and smoke reduced quite clearly, but NO_x emissions increased a bit when using ethanol-diesel blends as compared to conventional diesel.

Keywords: bio-fuel, diesel-ethanol blends, emissions, diesel engine

1. Introduction

In recent years, research and application of renewable fuels for vehicles are now interested in many countries. Among the biofuels, ethanol is a potential alternative fuel because it comes from renewable bio-based resource and it is oxygenated, thereby it is possible to improve the exhaust gas emissions. Ethanol has been used normally as commercial fuel in term of blending with gasoline to replace a part of fossil gasoline for gasoline engines [1,2]. Using blends with low percentage of ethanol such as 5% (E5) or 10% (E10) can improve engine power and fuel consumption as well as reduce remarkably HC and CO emissions [3]. Beside that ethanol might also be blended with diesel to use as fuel for diesel engine. However, ethanol-diesel blend has not been commercially used due to the difference in chemical and physical properties between ethanol and diesel fuel. At present, some investigations of the potential application of ethanol - diesel (ED) fuel blends on diesel engine have been carried out. Hansen et al [4] investigated the Cummins engine performance with 15% ED fuel blends and found that the engine power decreased by about of 7 to 10% and the brake thermal efficiency increased by about of 2 – 3% at rated speed. Kass et al [5] tested the torque output from the same model engine with two blends containing 10% and 15% ethanol and reported an approximate 8% engine power reduction for both fuel blends. Huang et al [6] investigated the engine performance and exhaust emissions of diesel engine when using 10%, 20%, 25% and 30% ethanol blended diesel fuels.

In that study, the results showed that the brake thermal efficiencies decreased with increasing amount of ethanol in the blended fuels. Rakopoulos et al. [7] studied the effects of ethanol blends with diesel fuel, with 5% and 10% (by volume) on the performance and emissions of a turbocharged direct injection diesel engine. The results showed that increasing the ethanol content in the fuel blend increased the brake specific fuel consumption and decreased the brake thermal efficiency. Results of [8,9] shows that diesel fuel blended with ethanol up to 10% volume can be used to solve the fuel shortage problems, increase the energy conversion efficiency, improve fuel economy and reduce its harmful emissions. Also using ED fuel blends on diesel engine can yield a significant reduction of carbon monoxide and nitrogen oxide [10] and particulate matter emissions [11,12]. In Vietnam, the government approved the scheme on development of biofuels up to 2015, with a vision to 2025 [13]. The E5 RON92 has been mandatorily used as fuel for gasoline vehicles over the country so far. However, Vietnam has a lot of potential for ethanol production from cassava; therefore it is necessary to study the abilitiy to use ethanol as fuel not only for in-use gasoline engine but also in-use diesel engine in Vietnam condition. This paper presents experimental results of performance and emissions of an in use diesel engine fuelled by ethanol-diesel blends with

* Corresponding author: Tel.: (+84) 979117492
Email: huynhinhutehy@gmail.com

5% ethanol and 95% diesel (called ED5) and 10% ethanol and 90% diesel (called ED10) by volume of ethanol. The ethanol fuel was produced in Vietnam and the experimental works were carried out at Laboratory of Internal Combustion Engines, Hanoi University of Science and Technology.

2. Experimental

2.1. Experimental apparatus

The test engine was a Hyundai D4BB diesel engine commonly used this is a four-stroke, four-cylinder, non-turbocharged engine on 1.25 ton Hyundai truck in Vietnam. The engine specifications are shown in Table 1.

Table 1. Engine specifications

Specification	Value
Engine model	Diesel engine D4BB, 4 cylinder
Injection sequence	1-3-4-2
Cylinder bore x Cylinder stroke	91,1mmx100mm
Rated power/ speed	59kW/4000 rpm
Rated torque/speed	165Nm /2200 rpm
Compression ratio	22
Injection pump	Mechanically in-line type
Early injection angle	5^0 BTDC

The engine was coupled to an electrical dynamometer to provide brake load, and equipped with the instrumentation for its control (Fig.1). The consumption of fuel and air was measured by a Fuel Balance AVL 733S, and Air Flow Meter Sensy flow P. The cooling water temperature, oil temperature and pressure, cylinder pressure, intake and exhaust gas temperatures and lambda value were also measured or monitored by sensors. For emissions analysis, an AVL Combustion Emission Bench (CEB II) and a Smoke Meter AVL 415 were installed and sampled the raw exhaust gas at the tail pipe. The CEB II comprises all analysers for HC, CO and NOx measurements. Additionally, the particle number in exhaust gas was also sampled and counted by the particle counting system that included a dilution system and a particle counter, developed at Laboratory of Internal Combustion Engine, Hanoi University of Science and Technology (HUST), Vietnam.

Based on the requirement of Particle Measurement Program (PMP) [14] the dilution system comprises a first dilution stage, a evaporation tube that was heated to 150^0C and about 300-400^0C respectively, and a second dilution stage which cooled the sample gas down to about 30^0C (*Fig 2*). In experiments, an ejector was used for first dilution stage in which clean compressed air produced an under pressure at the nozzle that drew the sample gas. The second diluter was the mixer in which sample gas and clean air were mixed. Dilution factors of the first diluter and the second diluter were defined by measuring related flow rates. The overall dilution factor of the system was product of two dilution factors mentioned above. A Miniature Diffusion Size Classifier (DiSCmini) manufactured by Testo was used to determine the particle number. The DiSCmini can detect particle number concentration up to 10^6 #/cm^3 with the size in the range of 20-700 nm with the sampling flow rate of 1 l/min. Although this particle counting system had not been calibrated and validated by PMP method, but the results of comparative measurement could provide useful information of the change in particle number in exhaust gas when using the different fuels.

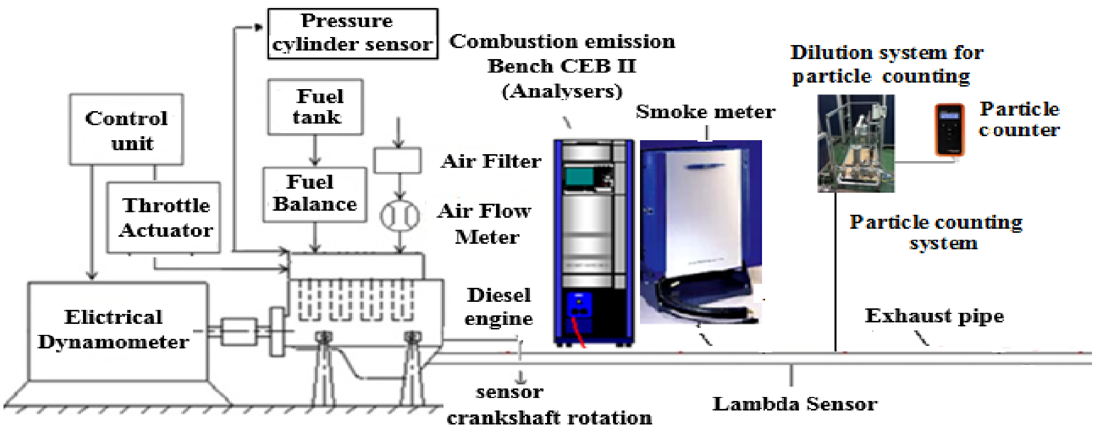

Fig. 1. Experimental setup

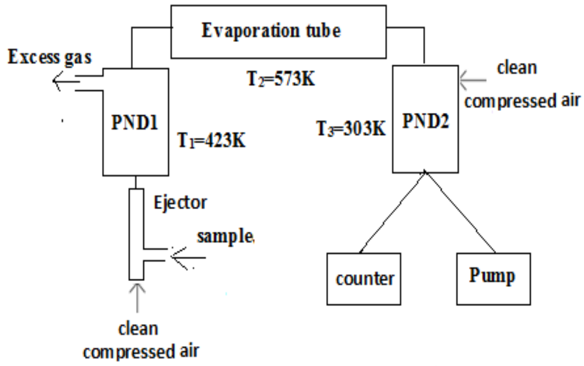

Fig. 2. Schematic of particle counting system developed at ICE Lab, HUST

2.2. Fuels

The test was conducted in order to assess engine performance and emission characteristics when using blends of 95% diesel fuel and 5% ethanol (ED5) and of 90% diesel and 10% ethanol (ED10) by volume. Properties of the diesel fuel that has 0.05% sulfur available in Vietnam market according to TCVN 5689-2005 and properties of the ethanol are provided in Table 2. The ethanol and diesel fuels were mixied together without any additive by an agitator. Right after blending, the blends were fueled to engine for testing.

Table 2. Properties of diesel and ethanol fuels [6]

Fuel properties	Diesel	Ethanol
Density at 15^{0}C (kg/m3)	838	780
Kinematic viscosity at 40^{0}C (mm2/s)	2.5	1.2
Lower heating value (MJ/kg))	43	26.8
Oxygen (% weight)	0	34.8
Cetane number	50	5-8
Surface tension at 20^{0}C, (N/m)	0.023	0.015
Molecular weight (kg/kmol)	170	46
Stoichiometric Air/fuel ratio	15.0	9.0
Latent heat of evaporation, (kJ/kg)	250	840
Boiling point (^{0}C)	180-360	78
Specific heat capacity, (J/kg ^{0}C)	1850	2100

2.3. Testing modes

In order to assess the effect of fuels on maximum engine power, the test was carried out at full load condition at which the speed varied from 1000rpm to 3500rpm with an increment of 500rpm. The engine performance and emissions were measured with diesel, ED5 and ED10 fuels in turn. The engine was not modified or adjusted throughout the test.

3. Results and Conclusions

3.1 Engine performance

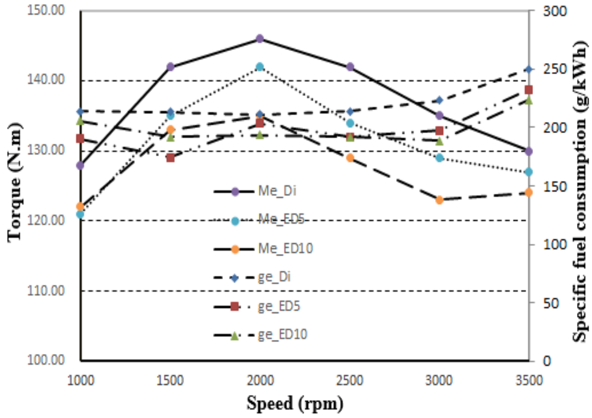

Fig. 3. Specific fuel consumption and torque

When using diesel-ethanol blends ED5, ED10 the engine torque decreased by 4.25% and 6.93%, fuel consumption increased by 10.23% and 9.78% on average over speed range, respectively, as compared to conventional diesel (Fig.3). It was due to the reduction in heating value of ethanol-diesel blends. The heating value of ethanol is about 26.8MJ/kg where as that of diesel is about 43MJ/kg. That means the heating value of ED5 reduces by 1.9% and of ED10 by 3.8% approximately.

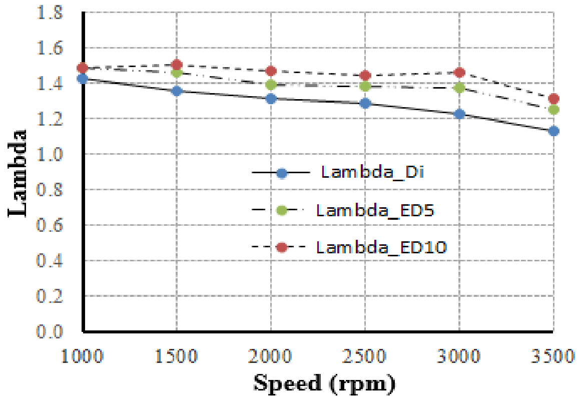

Fig. 4. Lambda values

In case of ED5 and ED10, the lambda values increased by 6.7% and 10.3% due to high oxygen content in ethanol (Fig.4).

At 2200rpm, the maximum cylinder pressure occurs at 9 crank angle degree after top dead center with all fuels but the highest pressure is 76.92bar observed with ED5.

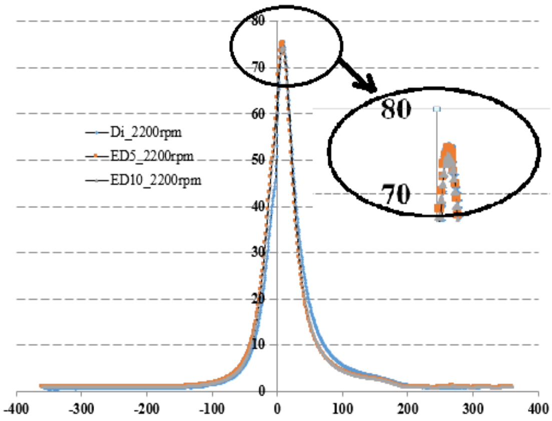

Fig. 5. Variable pressure in the cylinder at 2200 rpm

3.2. Engine emissions.

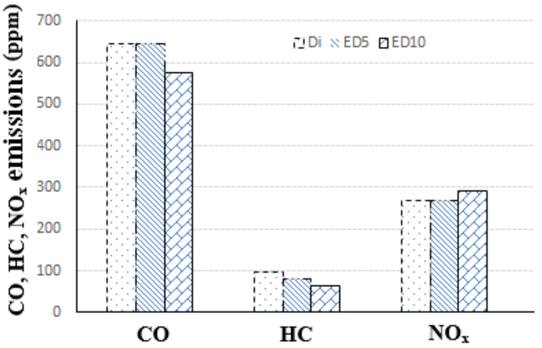

Fig. 6. Average CO, HC, NO_x emissions

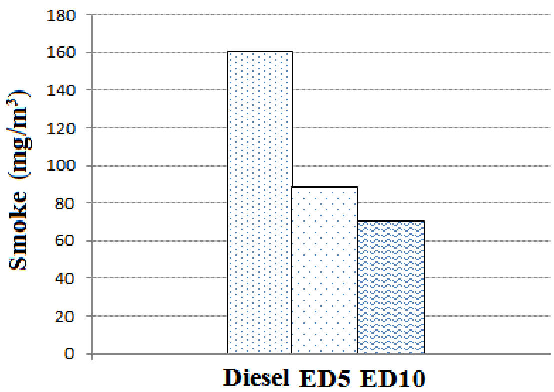

Fig. 7. Smoke

Emissions including CO, HC, NO_x and smoke were measured at each testing mode (Fig.6, Fig. 7). For CO emissions, ethanol has about 34% of oxygen, so that ethanol-diesel blends contain amount of oxygen which can enhances the complete and clean combustion that decreases CO, HC and soot missions. On average, CO reduces by 16.08% and 25.14%.

HC reduces by 17.49% and 34.78% and smoke reduces by 45.21% and 56.59% with ED5 and ED10 respectively. ED5 and ED10 have a smaller C/H ratio than conventional diesel that may be another reason leading to the results above.

However, higher oxygen content in fuels may also cause the higher NO_x emissions. It seems that NO_x emission doesn't change much with ED5 fuel, but it increases by 8.13% with ED10. NO_x emission formation is highly dependent on combustion temperature, along with the concentration of oxygen present in combustion products. NO_x reduction is one of the challenges for present-day diesel engines.

3.3. The number of particles in the exhaust gas.

The number of particles in the exhaust gas was measured at each modes with all the fuels. It showed that ED5 and ED10 produced lower particle number than diesel fuel in most cases, however, this trend varied in some other cases. It is known that the particle number in exhaust gas is very sensitive to engine operation condition [14]. On average, the particle number decreased by 8.48% and 37.38% with ED5 and ED10 compared to diesel fuel (Fig.8). This result agrees with the reduction of smoke mentioned above and one more time it shows that the combustion process with ED5 and ED10 is better than that with conventional diesel.

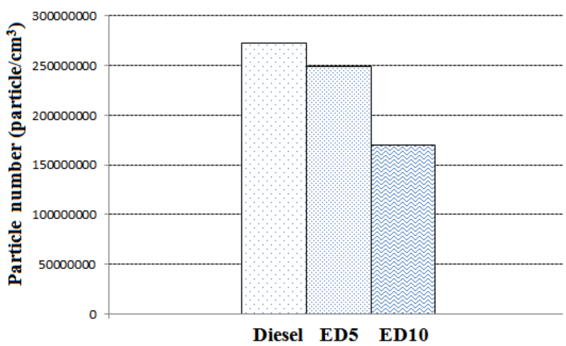

Fig. 8. Number of particles

4. Conclusion

The influences of the ethanol-diesel blends ED5 and ED10 on the diesel engine have been studied. Result showed that the engine performance does not change much when using the blends. On the aspect of emissions, fuelling these blends reduced quite clearly HC, CO and smoke emissions. Moreover the number of particles in the exhaust gas decreased with ED5 and ED10 compared to diesel fuel over the speed range. However, NO_x emissions increase with ED10 but decreased with ED5. These results may contribute to application of ethanol as an alternative fuel not only for gasoline but also for engines to enhance consumption and production of ethanol in Vietnam.

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