Performance and Exhaust Emission Characteristics of a CI Engine Fueled with Diesel-Nitrogenated Additives

Mojtaba Saei Moghaddam, Mohammad Mataei Moghaddam, Sina Aghili, Ali Absalan and Ali Najafi

***Abstract*—In this study, Nitromethane (NM) and Nitroethane (NE) were used as nitrogenated additives to improve brake specific fuel consumption (BSFC), combustion performance and reduce emission from diesel engine. The physico-chemical properties of the blended fuel and standard diesel were studied. Then exhaust emission of compression ignition (CI) engine have been evaluated experimentally for sole diesel, NM-Diesel and NE-Diesel fuel blends. In this section experimental study was carried out on ECE R-96 8-modes cycle. The addition of nitrogenated additives to the standard diesel fuel caused brake thermal efficiency (BTE) increased. The smoke emission decreased at the maximum torque speed (1500 rpm) rather than at the rated power speed (2200 rpm).**

***Index Items*—Diesel fuel, nitrogenated additives, oxygenated additives, BSFC.**

I. Introduction

The increasing use of diesel engines had led to considerable activity in methods for better performance and reduction in smoke and particle levels emitted in the exhaust. The required levels are difficult to achieve through engine design alone even with high grade fuels. But, blending different additives into diesel fuel is still today the best way to have results in matter of pollution [1-4]. One group of fuel additives is oxygenated compounds. The main reason of using oxygen to produce a cleaner burning of diesel fuels is few decades old [5]. The reduction of soot generation by the addition of oxygenated compounds depends on the molecular structure and oxygen content of the fuel [6]. This also depends on the oxygen concentration in the fuel plume [7]. In order to reduce soot generation, oxygen- Bearing chemicals should be blended with diesel to produce a composite fuel containing 10-20% V/V of oxygenate [8]. Change in the composition of diesel and the use of additives directly affect physical and chemical properties such as viscosity, density, volatility, and the cetane index [9-11]. Meanwhile nitrogenated additives have high oxygen content therefore are considered as oxygenated additives also. The nitrogenated additives increase performance as predicted by considerations of product evolution and of thermal energy in the fuel-air mixture [12]. The most important consideration in the application of fuel additives such as nitrogenated additives to engines is their mode of combustion and decomposition, and particularly the composition of the products [13]. In this paper nitrogenated additives are suggested as a class of chemical additives for blend in diesel fuel to increase the engine performance without an attendant penalty of increasing engine size or mechanical complexity.

Manuscript received April 2, 2012; revised June 11, 2012.

Mojtaba Saei Moghaddam is with Department of Chemical Engineering, Quchan Institute of Engineering and Technology (e-mail: mojtabasaei@gmail.com).

Mohammad Mataei Moghaddam was with Department of Inspection Engineering, Petroleum University of Technology, Abadan.

Sina Aghili is with Department of Chemical Engineering, Azad University of Quchan.

Ali Absalan is with Information and Communication Technology Organization Of Mashhad Municipality.

Ali Najafi is with Waste Management organization Of Mashhad Municipality.

II. Materials and Experimental Apparatus

A. Materials

Physical and chemical properties of diesel and nitrogenated additives were used in this test are shown in Table I.

TABLE I: Physical and Chemical Properties of Diesel and Additives

	Formula	Molecular Weight	Boiling Point °C	Auto ignition Temperature °C	Flash Point °C	Density at 20 °C kg/m³	Oxygen Content %wt	Lower heating value MJ/Kg	Latent heat of vaporization KJ/Kg
Diesel	C_xH_y	190-220	180-360	315	60-80	829	0	42.5	250
NM	CH_3NO_2	61.04	162	418	67-70	1138	52.4	10.52	561
NE	$C_2H_5NO_2$	75.067	100-103	414	35	1045	42.6	18.1	490

In this study additives blended with diesel fuel 10% in volume. Physical property tests which are consist of density, cetane index and viscosity were carried out. The densities of three fuels which are measured by D 1298 ASTM method were not changed significantly. As shown in Fig. 1, by use of additives, fuel viscosity was decreased. Fig. 2 shows the cetane index for three kinds of fuels according to D 976 ASTM method.

The cetane index of the Diesel fuel with and without additives was calculated from the following equation:

$$CI = 454.74 - 1641.416D + 774.74D^2 - 0.554B + 97.803(\log B)^2 \quad (1)$$

DOI: 10.7763/IJCEA.2012.V3.219

where:

D = density at 15 ℃, g/mL, determined by Test Method D 1298, and B = mid-boiling temperature, °C, determined by Test Method D 86 and corrected to standard barometric pressure.

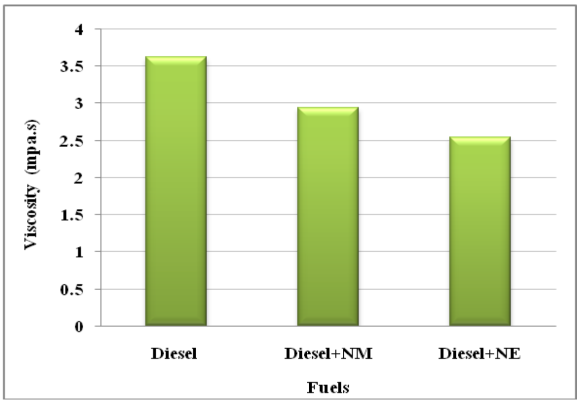

Fig. 1. Viscosity for three kinds of fuels

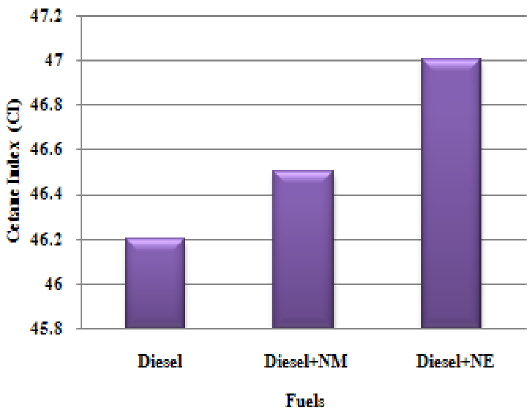

Fig. 2. Cetane Index for three kinds of fuels

B. Experimental Setup

Experiments were carried out on a commercial direct injection, water cooled, four cylinders, in-line, turbocharged aspirated diesel engine whose major specifications are shown in Table II. The engine was coupled with an eddy current dynamometer to measure the engine power. The engine operating condition was shown in Table III.

TABLE II: SPECIFICATIONS OF TEST ENGINE

Mode NO.	Engine Speed (RPM)	Percent Load (N.M)
1	2200	100
2	2200	75
3	2200	50
4	2200	10
5	1500	100
6	1500	75
7	1500	50
8	760	0.5

III. RESULTS AND DISCUSSION

A. Engine Performance

Fig. 3 shows the brake specific fuel consumption (BSFC) curves of the engine for three kinds of fuels according to ECE 8-mode cycles. The BSFC ranged 220–270 g/kWh except at the low-load and rated power conditions (mode 4). The BSFC curves of the fuels were significantly different at low-load conditions, and increased by about 12.7% when NM– diesel blend fuel was used. The fuel consumption rate increased at the rated power speed (2200 rpm) rather than at the maximum torque speed (1500 rpm).

TABLE III: OPERATING CONDITION

Engine Type	MT4.244
Bore* Stroke	100 *127
Displacement	3.99 L
Compression ratio	17.5
Injection Type	Direct Injection
Fuel Injection Pump	Rotary
Injection Pressure	400-450 bar
Maximum Power	61.5 kW @2200 rpm
Maximum Torque	340 N.m@1500rpm

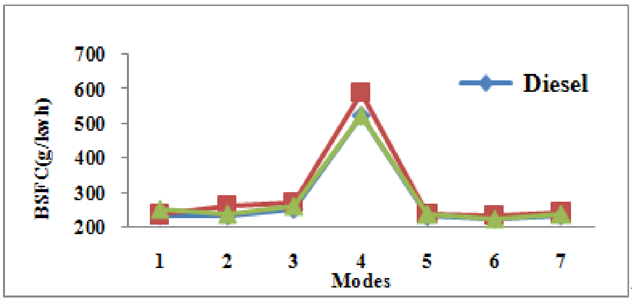

Fig. 3. Brake specific fuel consumptions according to 8-mode cycles

Fig. 4 shows the effect of fuel additives on brake thermal efficiency. The brake thermal efficiency could be estimated from the BSFC and lower heating value (LHV) of the three different fuels. Following equation was used to calculate the BTE was:

$$BTE=3600/ (BSFC\ (g/kWh)\ QLHV\ (MJ/kg)) \qquad (2)$$

where LHV of NM, NE and diesel fuel are 10.52, 18.1 and 42.5 MJ/kg, respectively. However, in spite of the large quantity of injected fuel, the brake thermal efficiency of the nitrogenated additives was higher than that of the diesel. This result shows that it has higher reaction activity in the fuel-rich zone due to oxygenate of them in high speed and high-load conditions. The higher brake thermal efficiency of the fuel additives is due to the following reasons: since the boiling point of additives is lower than that of diesel; thus quality of the spray with blend fuels was improved. Higher reaction activity in the fuel-rich zone due to oxygenate of them [14].

DOI: 10.7763/IJCEA.2012.V3.219

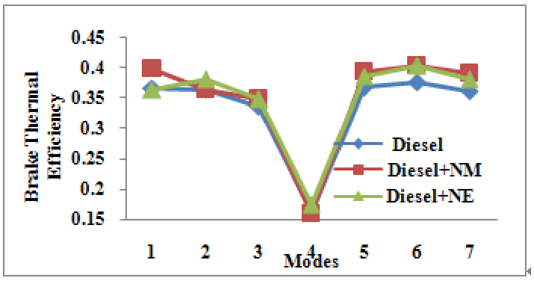

Fig. 4. Brake thermal efficiency according to 8-mode cycles

B. *Emissions Characteristics*

Results of exhaust emissions shown in the below Figures. These figures shown with add these additives, values of exhaust emission changed and in continue role of them investigated.

Fig. 5 shows the NO_x emission in each mode. The NO_x emission increases with the increase of the load.

Fig. 6 shows smoke for four kinds of fuels according to 8 modes. The smoke emission can be reduced by using both of additives. The decrease of smoke emission using additives can be explained by the enrichment of oxygen content of them. The diesel engine has trade-off relationship between NO_x emission and soot generation [2]. Smoke emission decreased more in the rated power speed range than in maximum torque speed range. In all modes, the average smoke reduction rates of NM-10 and NE-10 were 16.2% and 35.7% of that of sole Diesel respectively.

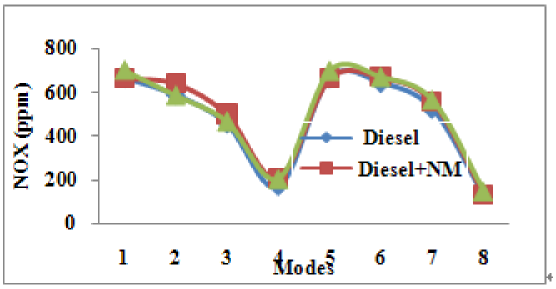

Fig. 5. NO_x concentrations of three kinds of fuels

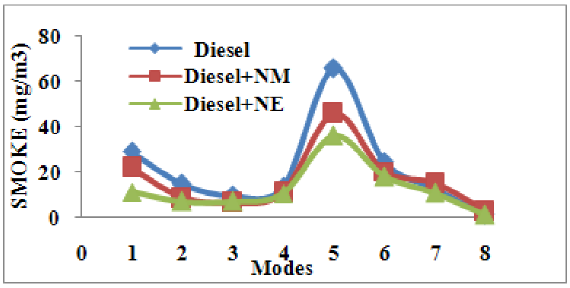

Fig. 6. Smoke emission for three kinds of fuels

IV. Conclusion

Overall, NE has been found to be promising fuel additive in compare with another additive, capable of providing high thermal efficiency, low soot levels and decreased viscosity but have high level of NOx at the maximum torque speed (1500 rpm). Nitrogenated additives increased brake thermal efficiency (BTE), in all modes, the average smoke reduction rates of NM-Diesel and NE-Diesel were 16.2% and 35.7% of that of sole Diesel respectively.

References

[1] E. Aneggi, C. D. Leitenburg, G. Dolcetti, A. Trovarelli, “Diesel soot combustion activity of ceria promoted with alkali metals,” *Catalysis Today*, vol. 136, 2008, pp. 3–10.

[2] H. Kim and B. Choi, “Effect of ethanol–diesel blend fuels on emission and particle size distribution in a common-rail direct injection diesel engine with warm-up catalytic converter,” *Renewable Energy*, 2008.

[3] T. Kitamura, T. Ito, J. Senda, and H. Fujimoto, “Detailed Chemical Kinetic Modeling of Diesel Spray Combustion with Oxygenated Fuels,” *Copyright Society of Automotive Engineers, Inc*, 2001.

[4] D. P. Juan, “Additive to improve combustion in internal combustion engines and boilers,” *European patent*, 2003.

[5] A. C. Hansen, M. R. Gratton, and W. Yuan, “Diesel engine performance and NOx emissions from oxygenated biofuels and blends with diesel fuel,” *Trans ASABE*, 2006, vol. 49, no. 3.

[6] T. C. Zannis and D. T. Hountalas, “DI diesel engine performance and emissions from the oxygen enrichment of fuels with various aromatic content,” *Energ Fuel*, 2004, vol. 18, no. 3, pp. 659–66.

[7] N. M. Ribeiro, *et al.*, “The Role of Additives for Diesel and Diesel Blended (Ethanol or Biodiesel) Fuels: A Review,” *Energy Fuels*, 2007, vol. 21, no. 4, pp. 2433-2445.

[8] C. A. S. Tseh, “Effects of oxygenates blended with diesel fuel on particulate matter emissions from a compression–ignition engine,” *Doctoral dissertation, Berkeley, Auckland: University of California*, 2002.

[9] M. Tamanouchi, T. Akimoto, S. Aihara, H. Morihisa, “Effects of DGM and oxidation catalyst on diesel exhaust emissions,” *SAE Technical*, 1999.

[10] G. Yanfeng, L. Shenghua, G. Hejun, H. Tiegang, and Z. Longbao, “A new diesel oxygenated additive and its effects on engine combustion and emissions,” *Applied Thermal Engineering*, vol. 27, 2007.

[11] X. C. Lu, J. G. Yang, W. G. Zhang, and Z. Huang, “Effect of cetane number improver on heat rate and emission of high speed diesel engine,” *Fuel*, 2004, vol. 83.

[12] P. A. Z. Moghadam, F. Ommi, and M. R. Omidkhah, “Investigation of oxygenate and nitrate component additive on Physico-chemical properties and exhaust emission of diesel fuel,” *Fuel and Combustion*, vol. 1, no. 2, 2008.

[13] D. Jacques, M. Xavier, M. Philippe, E. Daniele, *Formulations of nitrogenated additives for engine fuels and the engine fuels containing them*, 1990.

[14] Q. Zhang, W. Li, D. C. Lin, N. He, and Y. Duan, “Influence of nitromethane concentration on ignition energy and explosion parameters in gaseous nitromethane/air mixtures,” *Hazardous Materials*, vol. 185, pp. 756-762, 2011.

DOI: 10.7763/IJCEA.2012.V3.219