2011 2nd International Conference on Environmental Engineering and Applications
IPCBEE vol.17 (2011) © (2011) IACSIT Press, Singapore

Improvement fuel properties and emission reduction by use of Diglyme-Diesel fuel blend on a heavy-duty diesel engine

Mojtaba Saei Moghaddam[1]*, Abdolsamad Zarringhalam moghaddam[2], Nooshin Gholipour Zanjani[2], Erfan Salimipour[3]

[1]Department of Chemical Engineering, Quchan Institute of Engineering and Technology, Po.box 94717-84686 I.R.Iran

[2]Department of Chemical Engineering, Tarbiat Modarres University, Tehran, Po.box 14115-218 I.R.Iran

[3]Department of Mechanical Engineering, Quchan Institute of Engineering and Technology, Po.box 94717-84686 I.R.Iran

Abstract. In this study, diethylene glycol dimethyl ether (Diglyme) was used as an additive to improve fuel properties. The physico-chemical properties and the exhaust emission of the blended fuel and standard diesel were studied. Then exhaust emission of heavy-duty diesel engine have been evaluated experimentally for sole diesel and diglyme-diesel fuel blend. In this section experimental study was carried out on ECE R-96 8-modes cycle. The addition of diglyme to the standard diesel fuel caused significant changes in cetane index, viscosity and flash point temperature, but density which is measured by D 1298 ASTM method was not change significantly. The result from the operation of diesel engine with diglyme showed a significant reduction in smoke emission. In all modes, the average smoke reduction rate of diglyme-diesel fuel blend was 20.5% of that of standard diesel respectively. NO_x emission decreased in maximum torque speed range (modes 5,6 and 7) more than in the rated power speed range (modes 1,2,3 and 4). By use of Diglyme, BSHC increased but BSCO decreased. In general low smoke and CO emission was measured with the diglyme-diesel fuel blend.

Keywords: Diesel fuel, Diglyme, Emission reduction

1. Introduction

Due to their better drivability, fuel efficiency and torque capacity diesel engines are widely used in industrial and transportation. The disadvantage of diesel engine is emission of harmful exhausts such as smoke and particulate emissions [1, 2]. With the increasing apprehension for environmental protection and human health, stringent regulations are enforced all over the world. Therefore one of main researches in field of engine development is reduction of engine emissions. To achieve necessary standards in emission, some improvements in engine design such as fuel injection control, common rail system and exhaust gas recirculation was implemented but these changes aren't usually economic and lead to fuel consumption increase [3-6]. Fuel improvement could be an effective way to decrease emission in diesel engines combustion [7-8]. Diglyme is a suitable oxygenated additive for diesel engine. Researches of Zannis et al and Ren et al have shown that adding this material to diesel fuel, make a delay in the ignition time and the amount of heat release decreases in premixed combustion but it increases in diffusive combustion phase. Also, in the emission aspect, smoke concentration decreases but NOx emission can either decrease, increase or do not change [9-13].

This paper, the Influence of diethylene glycol dimethyl ether (Diglyme) additive on the physico-chemical properties of standard diesel fuel, such as density, viscosity, cetane index and flash point was

* Corresponding author. (Tel.:+989359462396; fax:+985812238488)
E-mail: (mojtabasaei@gmail.com)

studied. Also, NOx emission and smoke concentration of heavy-duty diesel engine have been evaluated experimentally for sole diesel and diglyme-diesel fuel blend.

Nomenclature

HC	hydrocarbon	LHV	lower heating value
CO	carbon monoxide	BSSOOT	brake specific soot
CO_2	carbon dioxide	BSHC	brake specific hydrocarbon
NO_x	oxides of nitrogen	$BSNO_x$	brake specific oxides of nitrogen
PM	particulate matter	BSCO	brake specific carbon monoxide
CI	cetane index		

2. Materials and Experimental apparatus

2.1. Materials

Diethylene glycol dimethyl ether (Diglyme) and standard diesel was used in this article. Table 1 compares some Physical and chemical fuel properties of diglyme and diesel. Diglyme is a clear, colorless liquid, molecular formula is $C_6H_{14}O_3$, The oxygen content is 36% wt and it can be produced in industrial scale by different methods. Lower heating value and boiling point of diglyme are 24.5 MJ/Kg and 162 °C, respectively. These are lower than that of diesel fuel, which is affected on the engine power output, respectively.

Table 1 Physical and chemical properties of diesel and diglyme

	Formula	Molecular Weight	Boiling Point °C	Viscosity at 20 °C mpa.s	Flash Point °C	Density at 20 °C kg/m^3	Oxygen Content %wt	Lower heating value MJ/Kg	Latent heat of vaporization KJ/Kg
Diesel	$C_x H_y$	190-220	180-360	3.1	60-80	839	0	42.5	250
Diglyme	$C_6 H_{14} O_3$	134.174	114-116	2.0	30	945	36	24.5	310

In order to investigate the effects of the diglyme –diesel blend on Physical and chemical properties of fuels and engine's emissions, standard diesel fuel and blend of diesel with 10% diglyme by volume were prepared and tested.

2.2. 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 2. The engine was coupled with an eddy current dynamometer to measure the engine power. The engine operating condition was shown in Table 3.

Table 2- Specifications of test engine

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

Table 3- Operating condition

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

3. Result and discussion

3.1. Physicochemical properties

Physical property tests which are consist of density, viscosity; cetane index and flash point temperature were determined. As shown in Table 4 the density of both fuels which is measured by D 1298 ASTM method were not changed significantly and by addition of diglyme to the standard diesel fuel viscosity and flash point temperature were decreased, but cetane index which is measured according to D 976 ASTM method increase for blended fuel.

Table 4 Physical property tests for both fuels

	Standard diesel	Diesel-Diglyme
Density (Kg/m^3)	839	836
Viscosity (mpa.s)	3.1	2.8
Cetane Index	48.2	52
Flash Point Temperature (°F)	158	149

3.2. Emissions characteristics

Fig. 1 shows NO_x emission for standard diesel and diesel-diglyme fuel according to ECE R-96 8-modes cycles. The NO_x emission increased with the increase of the load. In the rated power speed condition (modes 1, 2 and 3) the NOx formation was lower than maximum torque speed. when diglyme added to the standard diesel NO_x emission decreased in maximum torque speed range (modes 5,6 and 7) more than in the rated power speed range (modes 1,2,3 and 4), the NO_x reduction rate were 2%, 4.7% and 6.1% of that of standard diesel, in the rated power speed range (modes 1,2,3 and 4) respectively.

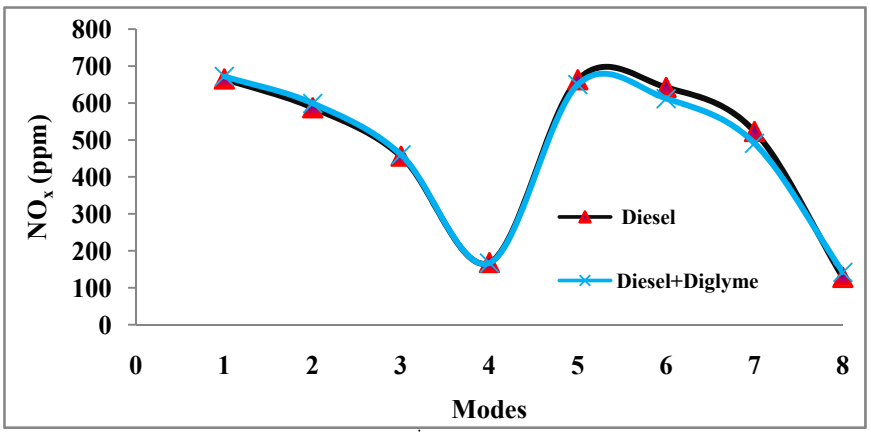

Fig.1. NO_x concentrations for two kinds of fuels

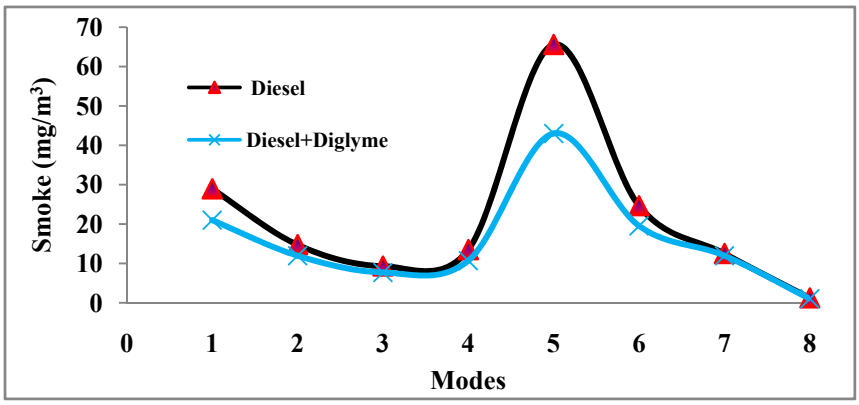

Fig.2. Smoke concentrations for two kinds of fuels

Fig. 2 shows smoke concentration for two kinds of fuels according to ECE R-96 8-modes cycles. In general, the addition of diglyme in diesel decreases the smoke concentration; the decrease of smoke emission using diglyme can be explained by the enrichment of oxygen content of it [9-13]. At lower loads smoke concentration of diesel-diglyme blend fuel slightly decrease in comparison with standard diesel fuel. At higher loads, smoke concentration decreases significantly. The smoke concentration decreased in maximum torque speed range (modes 5,6 and 7) more than in the rated power speed range (modes 1,2,3 and 4). In all modes, the average smoke reduction rate of diglyme-diesel fuel blend was 20.5% of that of standard diesel respectively.

Table 5 shows the emission of BSHC, BSCO, BSSOOT and BSNOX for both of fuels according to ECE 8-mode cycles in g/kWh. HC emission of diesel-diglyme blend fuel increased respectively because of the high heat of vaporization of diglyme, slow vaporization and mixing of fuel and air due to the high heat of vaporization [14].CO concentration of diesel-diglyme blend fuel was lower than that of Diesel because premixed combustion was reduced by high cetane index.

In general low smoke and CO emission was measured with the diglyme-diesel fuel blend.

Table 5-The emission of BSHC, BSCO, $BSNO_x$ and BSSOOT according to 8-mode cycles

	Diesel-Diglyme	**Diesel**
BSHC (g/kWh)	0.078	0.023
BSCO (g/kWh)	0.22	0.49
$BSNO_X$ *10^3 (g/kWh)	5.99	5.83
BSSOOT (g/kWh)	0.12	0.16

4. Conclusions

The addition of diglyme to the standard diesel fuel caused significant changes in cetane index, viscosity and flash point temperature, but density did not change significantly.

Overall, Diglyme has been found to be promising fuel oxygenate additive, providing low soot levels, high cetane index and decreased viscosity but have slightly effect on level of NO_x emission at the rated power speed (2200 rpm).

In all modes, the average smoke reduction rate of diglyme-diesel fuel blend was 20.5% of that of standard diesel respectively.

5. References

[1] Eleonora Aneggi , Carla de Leitenburg, Giuliano Dolcetti, Alessandro Trovarelli. Diesel soot combustion activity of ceria promoted with alkali metals. Catalysis Today 136 (**2008**) 3–10.

[2] Hwanam Kim, Byungchul 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**.01.002.

[3] De Menezes, E. W.; Da Silva, R.; Cataluna, R.; Ortega, R. J. C. Effect of ethers and ether/ethanol additives on the physicochemical properties of diesel fuel and on engine tests Fuel, 85, **2006**, 815-822.

[4] Nbia M. Ribeiro & et al. The Role of Additives for Diesel and Diesel Blended (Ethanol or Biodiesel) Fuels: A Review. Energy Fuels, **2007**, 21 (4), 2433-2445.

[5] F. Frusteri, L. Spadaro, C. Beatrice and C. Guido Oxygenated additives production for diesel engine emission improvementChemical Engineering,134, **2007**, 239-245..

[6] Mingfa Yao, Hu Wang, ZunqingZheng and Yan Yue Experimental study of n-butanol additive and multi-injection on HD diesel engine performance and emissions. Fuel 89, **2010**, 2191-2201

[7] V.Pirozfar, A.Z.Moghadam, F.Ommi, 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, Fall **2008**

[8] Miyamoto N, Ogawa H, Nurm NM, Obata K, Arima T. Smokeless, low NOx, high thermal efficiency, and low noise diesel combustion with oxygenated agents as main fuel. SAE paper 980506; **1998**, 57-63.

[9] Zannis TC, Hountalas DT. DI diesel engine performance and emissions from the oxygen enrichment of fuels with various aromatic content. Energy Fuel **2004**; 18(3):659–66.

[10] Yage Di, C.S. Cheung, Zuohua Huang. Experimental investigation of particulate emissions from a diesel engine fueled with ultralow-sulfur diesel fuel blended with diglyme. Atmospheric Environment (**2009**) 1–9.

[11] Yi Ren, Zuohua Huang, Haiyan Miao, Yage Di, Deming Jiang, Ke Zeng,Bing Liu, Xibin Wang. Combustion and emissions of a DI diesel engine fuelled with diesel-oxygenate blends. Fuel 87 (**2008**) 2691–97.

[12] Tamanouchi, M., Akimoto, T., Aihara, S., Morihisa, H., 1999. Effects of DGM and oxidation catalyst on diesel exhaust emissions. SAE Technical Paper No. **1999**-01-1137.

[13] Yi Ren, Zuohua Huang, Haiyan Miao, Deming Jiang, Ke Zeng, Bing Liu, and Xibin Wang. Effect of the Addition of Diglyme in Diesel Fuel on Combustion and Emissions in a Compression-Ignition Engine. Energy & Fuels **2007,** 21.

[14] Lu¨ XC, Yang JG, Zhang WG, Huang Z. Effect of cetane number improver on heat rate and emission of high speed diesel engine. Fuel **2004**;83:2013–20.