

Effect of Naco-Cerium Oxide and Water Additives On B5 Combustion Emissions

Taha Roodbar Shojaei
Chemical and Environmental
Engineering, University of
Putra Malaysia, Serdang,
Malaysia.
tahashojaei2000@yahoo.com

Esmail Khalife Mechanical
and Mechatronics
Engineering, Salahaddin
University, Erbil, Iraq.
esmailkhalife@gmail.com

Meisam Tabatabaei, Microbial
Biotechnology, Agricultural
Biotechnology Research
Institute of Iran, Karaj, Iran

Bahman Najafi, Biosystem
Engineering, University of
Mohaghegh Ardabili, Ardabil,
Iran

Mostafa Mirsalim,
Mechanical Engineering,
Amirkabir University of
Technology, Tehran, Iran.

ABSTRACT

The climate changes of car emission regulation recently requirement for cleaner engine combustion. Reduction of engine emission could play a key role on public health. Addition of 2-20% biodiesel into diesel fuel could significantly reduce exhaust emission. Biodiesel could improve engine combustion and reduce diesel gases except NO_x. Using additives is a successful way to diminish NO_x emission. Among fuel additives, water could effectively reduce NO_x emission beside other advantages. In present research, cerium oxide was employed to prevent disadvantages from thermal effect of water during combustion. In present study, emission characteristics of combustion of emulsified B5 (95% diesel fuel and 5% Biodiesel) containing 60 ppm cerium oxide and 5% water were scrutinized. Present findings showed that B5W6 emulsion fuel (B5 containing 6% water) reduced CO, HC, and NO_x emission effectively. Besides, results obtained showed that nano cerium oxide particles reduced more emission compared with B5W6.

Key words: Additive; Biodiesel; Nano cerium oxide; Diesel Engine; Emissions

1. INTRODUCTION

More than 50% of world overall greenhouse gases (GHGs) in the world belong to transportation and industrial sections. Diesel engines that are widely employed in this section need to be adapt with car emission regulations which become more strict year by year. Various investigations have been conducted to improve engine technologies to meet stringent car emission regulations (Sahin et al., 2014). In better word, a big part of GHGs is due to high amount of fossil fuel consuming. In regards to this, a lot of efforts have been done to decrease the dependence on fossil fuel by using alternative and renewable fuel. In recent few decades, Investigations proved well that it can be a reliable substitute for fossil fuel due to the its favorable properties such as non-toxicity, sulfurless, and biodegradability etc (Bautista et al., 2009). The common method of biodiesel production is alkaline transesterification which resulted in production cost reduction (Hajjari et al., 2014). Based on previous studies, biodiesel combustion could reduce CO (carbone monoxide), PM (particle matter), and HC (unburned hydrocarbons) emissions while increases NO_x emission probably (Zheng et al., 2008). Although engine modification could partially reduce NO_x emission, but fuel additive could highly reduce NO_x emission.

Inclusion of adding water could powerfully reduce exhaust gases especially NO_x emission (Ithnin et al., 2015). Water addition into diesel engine could be done in three different methods such as: direct water injection into combustion chamber, vaporizing water into inlet manifold, and emulsified with diesel fuel (Khalife et al., 2017). Using water-diesel emulsion fuel has been more considerable by different researchers because of its application does not require to add extra equipment in engine. Several studies have been done for discussing water effect on diesel engine combustion pollutants. For example, in 2013, Fahd et al. conducted a research to study the combustion of an emulsion fuel containing 10% water on a four-cylinder diesel engine and their result showed simultaneous NO_x and CO emissions reduction (Fahd et al., 2013). In another study, Ithnin et al. used four levels of water (5, 10, 15, and 20%) inclusion into diesel fuel and observed that water could effectively diminish PM, NO_x, and CO emissions (Ithnin et al., 2015).

Nano metal-based is another fuel additive which can improve combustion quality. Combination of Water diesel emulsion (WDE) with nano metal-based additive could lessen drawback of using water additive such as in cylinder temperature reduction. Few reports have been published on assessing combination of water and nano metal-based additives combustion. For instance, Farfaletti et al. in 2005 studied cerium oxide effect on WDE and their observation showed that the combination of these two additives could simultaneously cause NO_x, PM, and HC emissions reduction (Farfaletti et al, 2005). In 2007, Kao et al. reported the influence of simultaneous application of water and nona aluminum led to considerable NO_x emission reduction and increasing released heat (Kao et al. 2007). Lately, Khalife et al. (2017) studied three different low water levels addition of water (3, 5, and 7%) in combination with 90 ppm cerium oxide into biodiesel-diesel (B5) fuel blend. Their result showed an improvement in exhaust gas emissions compared with B5W3 (B5 containing 3% water) while this improvement was not achieved in comparison with B5 and neat diesel on all emissions (Khalife et al.2017).

In general, there are few information about combustion effects of emulsified nano cerium oxide and water additives with biodiesel-diesel on engine exhaust pollutants. The subject of present study is to investigate the exhaust emissions caused by combustion of 6% (wt) water and 60 ppm cerium oxide on B5.

2. MATERIALS AND METHODS

Biodiesel was producing by using transesterification process pretreated WCO (waste cooking oil) with Methanol and KOH (potassium hydroxide) as catalyst by following methods described by Khalife et al. (Khalife et al., 2017). Washing method was employed by aeration to avoid consuming high water. 6% wt. water was included into 1 litter biodiesel and sonicated by an ultrasonication bath for 10 minutes and at room temperature. Afterward, cerium oxide was solved into B5W6 to obtain B5W6M60 (B5W6 containing 60 ppm cerium oxide). In present study 50 ml surfactant was used for stabilizing emulsion fuel samples.

Experimental engine tests were carried out on a Yanmmar L48N model four stroke single cylinder. A SPTC gas analyzer was employed to measure HC, CO₂, CO, and NO_x emissions. Engine tests was done at full load and four engine speeds 1000, 1500, 2000, and 2500 rpm. Schematic figure of engine setup is illustrated in Fig.1.

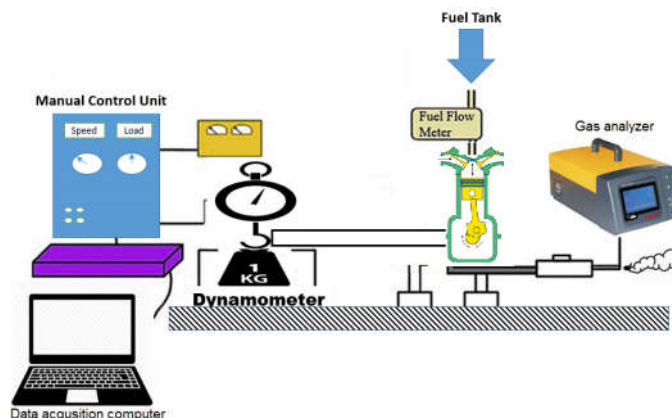


Figure 1. The experimental engine setup.

3. RESULTS AND DISCUSSIONS

3.1 Physical and chemical properties fuel samples

Results of acid composition of WCO is shown in Tab.1. Tab.2 presents physicochemical properties of obtained biodiesel and fuel samples. The results showed that produced biodiesel properties showed a good agreement with the American Society for Testing and Materials standards (ASTM D6751) values. Adding water into B5 reduced calorific value and increased viscosity. Also, adding cerium oxide into B5W6 increased viscosity and calorific value slightly. Indeed, increasing observed in viscosity value of B5W6M60 could be

attributed to the higher friction and static electricity attraction among the oil/water particles in the emulsion fuel leading to smaller and better dispersed particles (Lin and Chen, 2006).

Table 1. Fatty acid profile of the WCO.

acid composition	%
Myristic (C14:0)	0.71
Palmitate (C16:0)	33.18
Stearate (C18:0)	4.69
Oleic (C18:1)	42.02
Linoleic (C18:2)	18.09
Linolenic (C18:3)	1.03

Table 2. Physicochemical properties of fuel samples.

Fuel samples	Kinematic viscosity	Calorific value (Mj/kg)
Diesel	5.04	47.212
Biodiesel	6.10	37.384
B5	5.22	46.827
B5W6	6.40	43.116
B5W6M60	6.65	45.410

3.2 Emissions

3.2.1 CO emissions

Results of present study showed that the combustion of B5 decreased CO emission at high engine speed which could be due to the more complete combustion caused by oxygen present in biodiesel molecules structure.

Adding water into biodiesel-diesel fuel blend caused more CO emission reduction (Fig.2). This reduction was 12 and 15% in comparison with B5 and neat diesel fuel, respectively. CO emission reduction could be due to the happening of micro explosion phenomenon during combustion of emulsified diesel fuel with water (Hagos et al., 2011). Encapsulated water in the emulsion fuel vaporize before diesel due to the higher latent heat of vaporization (Fig.3)(Qi et al. 2010). This result was in agreement with findings of Debnath et al. who investigated combustion of WDE (containing 5% water) and reported 67% CO emission reduction (Debnath et al., 2013a).

Addition of cerium oxide into B5W6 caused more CO emission reduction. It means that presence of cerium oxide resulted more CO oxidation. B5W6M60 averagely reduced CO emission by 5% compared with B5W6.

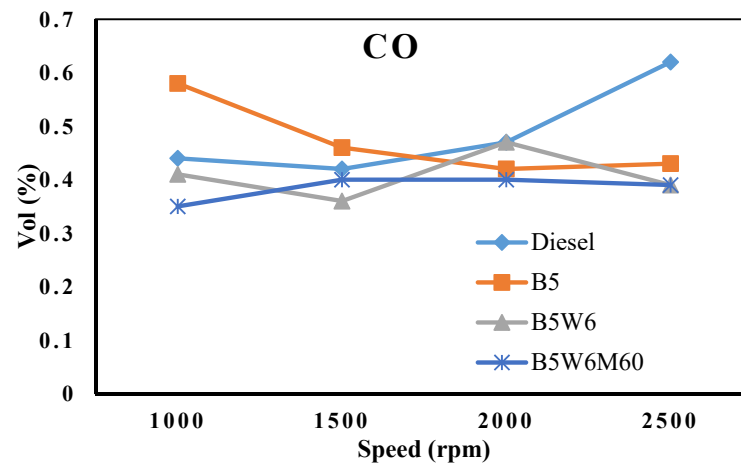


Figure 2. CO emission variations at different engine speeds.

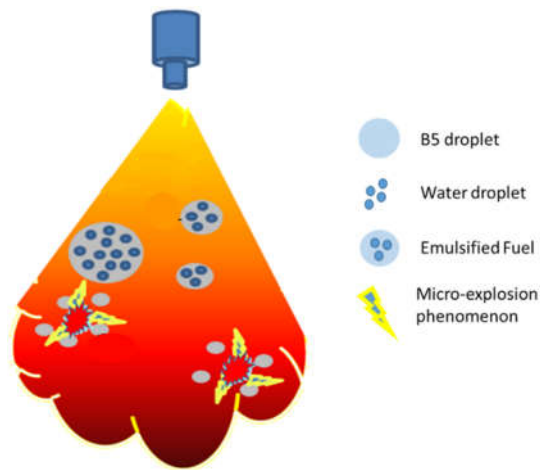
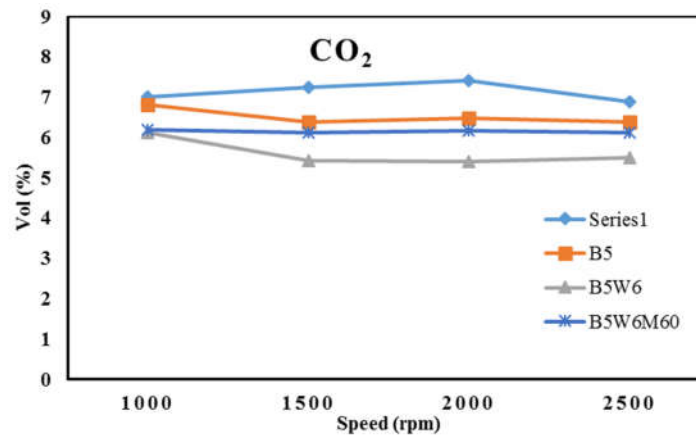


Figure 3. The process of micro explosion in the water-B5-metal emulsion.

3.2.2 CO₂ emission

Result of CO₂ emission is illustrated in Fig.4. As shown, combustion of B5 resulted in CO₂ emission reduction in comparison with neat diesel fuel which is in agreement with those of other researchers (Xue et al., 2011). This result could be because of high C/H ratio of biodiesel compared with neat diesel. Average CO₂ emission reduction of B5 was 9% compared with neat diesel fuel.

Figure 4. CO₂ variations at different engine speeds.

Cerium oxide has been found an increasing effect on CO₂ emission when included in B5W6 emulsion. This could be related to the fact that cerium oxide reacts as a catalyst by converting CO into CO₂ and consequently more complete combustion of B5W6M60.

3.2.3 HC emission

More complete combustion in cylinder has a direct influence on emitted HC pollutant. The observation of present study showed that the combustion of B5 resulted in considerably HC emission reduced in compare with neat diesel (Fig.(5)). This finding was in agreement with previous published researches which argued that the positive effect of biodiesel on HC emission is due to the oxygen presence in the molecular structure of biodiesel fuel (Al-Widyan and Tashtoush, 2002; Song and Zhang, 2008; Xue et al., 2011). For example, Al-Widyan and Tashtoush in a study determined the effect of biodiesel in different ratios (B5, B75, and B100) on engine performance and emissions then found the HC emission increased at high concentrations (Al-Widyan and Tashtoush, 2002). In addition, in the year of 2010, Kim and Choi conducted a research to evaluate biodiesel behavior at concentrations of B5, B10, B15, and B20 at different engine speed of a four-cylinder diesel engine. They concluded that the presence of oxygen in biodiesel was the main reason for HC emission reduction.

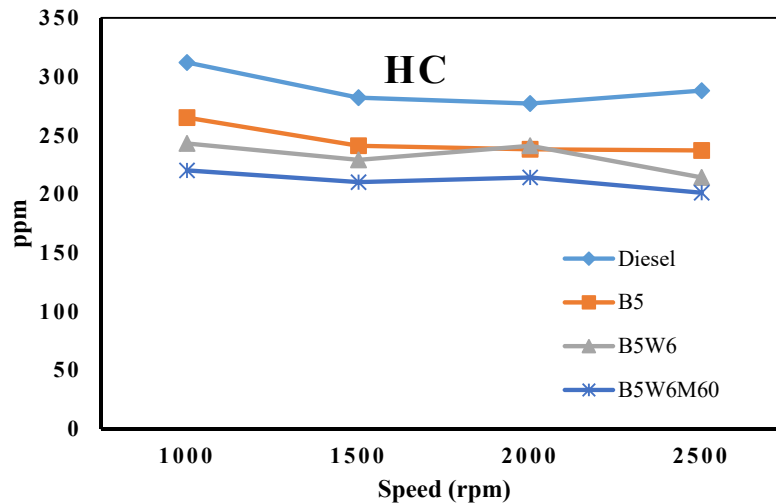


Figure 5: HC emission variation at different engine speeds.

The addition of 6% water into B5 reduced the HC values. This reduction could be explained by the occurrence of the micro explosion phenomenon leading better combustion. In case of the emulsified fuel blend containing cerium oxide results showed more HC emission reduction. Their finding is in agreement with those of the previous studies who investigated on metallic based additives impacts on combustion. For instance, Ganesh and Gowrishankar investigated on the combustion of biodiesel that containing Al-Mg and cobalt oxide. They reported these additives reduced HC emission significantly (Ganesh and Gowrishankar, 2011). The result of present study is has been proved by previous researcher, for instance, Selvan et al. who investigated on cerium oxide additive inclusion into biodiesel-diesel-ethanol (Selvan et al., 2009).

3.2.4 NOx emission

Principally reducing NOx emission is the key objective of adding water as additive into biodiesel/diesel fuel blends. This happens because of the fact that NOx emission occurs at high in cylinder temperature (Glaude et al., 2010). Water could effectively reduce cylinder temperature due to the its cooling property and consequently decrease NOx emission.

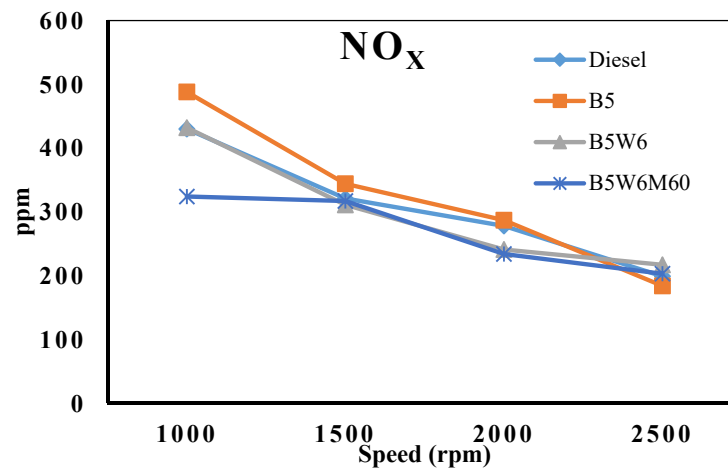


Figure 6. NOx emission variation at different engine speeds.

Fig.6 reveals NOx emission variation of different fuel samples. As presented, the combustion of B5 led to higher NOx emission than neat diesel fuel one and this is because of oxygen presence in biodiesel (Xue et al., 2011).

In this study, cerium oxide inclusion into the B5W6 decreased NOx emission compared with cerium oxide-free B5W6. Average measured reduction were 5 and 2% compared with B5 and neat diesel, respectively. Similar results were reported by other researchers on water influence on NOx emission reduction. for instance, Davis et al. conducted a study on emulsified B20 containing 20% water and reported that water has considerable impact on NOx emission reduction (Davis et al., 2012). Even in a different research, Koc and Abdullah in an investigation on combustion of water-biodiesel-diesel emulsion blend found that water decreased 8% NOx emission in comparison with biodiesel-diesel fuel (Koc and Abdullah, 2013).

By adding 60 ppm cerium oxide into B5W6, NOx emission was more decreased (Fig. 6). This Reduction were 8, 12, and 10% compared with B5W6, B5, and neat diesel, respectively. This could be ascribed to the impact of catalytic impact of cerium oxide during combustion process.

4. CONCLUSIONS

An experimental study on the application of water (6 wt.%) and cerium oxide (60 ppm) into B5 fuel blend using a single cylinder diesel engine, was conducted and based on the results achieved the following conclusions could be drawn:

1. Calorific value was decreased by adding water into B5 while cerium oxide nano particles slightly compensated this reduction.
2. Both of water and cerium oxide deteriorated emulsion fuel blends viscosity.
3. The amount of CO emission decreased up to 5% averagely according to addition of cerium oxide into B5W6.
4. The adding water into B5 decreased HC emission and this reduction increased by adding cerium oxide nano particles into the B5W6 fuel blend due to the more complete combustion.
5. Although biodiesel increased NOx emission, but water inclusion into B5 effectively reduced NOx emission and this reduction tensed in presence of cerium oxide in the emulsion.

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