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Investigation of $CuNO_3$ as Diesel Fuel Additive

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Abstract

In this experimental study, influence of copper nitrate ($CuNO_3$) as diesel additive were investigated. The metallic base $CuNO_3$ additive were added into diesel fuel at the ratios of 50 ppm and 100 ppm in order to determine fuel and exhaust emissions characteristics. In preparation of $CuNO_3$ based additives, ultrasonic waves were utilized for dispersions of nanoparticles in diesel fuel. Viscosity, density, cetane number, copper strip corrosion and heating values of the test fuels were also determined. The fuel properties did not changed significantly as compared to diesel fuel. When heating values of the test fuels decreased, however cetane number, viscosity and density values increased slightly. Engine exhaust emission tests were carried out in a four cylinder direct injection diesel engine at full load conditions. According to the results obtained from emission tests, maximum decreasing ratios of hydrocarbon, carbon monoxide and smoke emission were found to be 31.57% at 3000 rpm with 50 ppm additives, 22.41% at 2800 rpm with 100 ppm additives and 66.86% at 2800 rpm with 50 ppm additives, respectively. NO emission values didn't changed apart from high engine speeds.

Keywords: Combustion, fuel additive, fuel properties, diesel engine, exhaust emissions

INTRODUCTION

Diesel engines have a great advantage in various fields such as transportation, agricultural and industrial applications. However, diesel engines produce harmful emissions. Therefore, great efforts have been made to reduce emissions from diesel engines [1,2]. The methods to lessen pollutants emission can be classified into different approaches; improved fuels quality and use of the alternative fuels. Use of metal nanoparticles as fuel additive is one of the alternative solution in order to enhance the combustion process and reduce the engine-out pollutants leading to improve after-treatment systems performance. These metal based additives include cerium (Ce), cerium–iron (Ce-Fe), platinum (Pt), platinum–cerium (Pt-Ce), iron (Fe), manganese (Mn), barium, calcium and copper [3].

The reduction of emission while using metal based additive may be either due to the fact that the metals react with water vapor to produce hydroxyl radicals or serve as an oxidation catalyst thereby reducing the oxidation temperature that results in increased particle burnout [3]. Nano particles as a fuel additive in CI engine have been investigated by many researchers. Nano size material includes metals like Al, Mg, Zr, Ti, Pa, Ni, Cu, boron [4,5]. Sajeevan et al. [6] experimentally investigated nano cerium oxide with concentration of 5-40 ppm on a single cylinder CI engine fueled with the diesel and cerium oxide blended diesel. Nano particles such as CuO, $CuCl_2$, $CoCl_2$, $FeCl_3$ and $CuSO_4$ were used by Kannan et al. [7]. Shafil et al. [8] used ferrofluid (Fe_3O_4) in diesel with the concentration of 0.4 and 0.8% by volume on the compression ignition engine. Nano metal oxide of manganese oxide (MnO) and copper oxide (CuO) with dosing 200 mg/l in diesel was used by Lenin et al. [9]. Kao et al. [10] used aluminum nano fluid additive with concentration varied from 30 cc to 50 cc per liter in diesel. Luman et al. [12] prepared several combination by dosing nano-sized aluminum particles and ultra-fine boron particles. It was found that the addition of nano-sized aluminum particles can enhance the propellant burning rate. Many studies have been conducted on the effect of nano fuel additives in order to control diesel engine emissions. Various metal additives such as nano metal oxide of manganese oxide (MnO) and Copper oxide (CuO) have been selected and doped with diesel for reaching more complete fuel combustion and reducing the amount of exhaust gases [9]. NOx emissions were found at relatively higher with the metallic-based additives such as iron, nickel, cobalt or copper probably due to the catalyst effect of metallic additives in the combustion process [9,10]. Hydrocarbon emissions is due to the incomplete combustion of fuel. Most of the researchers [13-16] reported that hydrocarbon emission was reduced by the addition of nano fuel additives. Cobalt oxide and mangalium additive showed a 75% reduction in HC emission at 75% load [13]. Some authors [17-19] observed decrease in CO emission due to improved ignition characteristics with nano fluid additives. However, at higher concentration of nano fluid additives, the higher CO emission was observed. Lower smoke emission was observed by most of the authors due to higher evaporation rate and reduced ignition delay [19]. Hence, more investigation are needed to determine the effect of different nanoparticles in the same base fuel. Especially, the optimum combination of concentration is important role to progress the combustion process leading to reduced emission. The main object of this study is to specify the effects of copper nitrate based additive with diesel fuel on exhaust emission of four cylinder direct injection diesel engine at full load conditions and catch the appropriate combination of blend fuels.

MATERIALS and METHODS

Preparing test fuels

In this study, copper nitrate based additive was added into diesel fuel at the dosage of 50 ppm and 100 ppm. These test fuels with additives were denoted as dose ratio and symbol of metal such as"Cu50". The fuel properties of the test fuels were determined at Cukurova University Fuel Analysis Laboratory. Instruments for analyzing of the test fuels were utilized as follows; Tanaka AKV-202 Auto Kinematic Viscosity test for measuring the viscosity; Zeltex ZX 440 NIR petroleum analyzer with an accuracy of ±0.5 device to analyze Cetane number; Kyoto electronics DA-130 for density measurement, IKA Werke C2000 bomb calorimeter for determination of calorific value. In this experimental study, nano CuNO3 particles were weighed by a digital balance machine to a predefined dosing level of 50 mg/L and poured into the base diesel fuel. Sonic Vibra-Cell VC 750 model ultrasonic processor at a frequency of 20 kHz under 750 W working power for 2 h. was used to disperse nanoparticles into diesel fuel homogeneously. The same procedure was performed to prepare the fuel blend with a dosing level of 100 mg/L.

Table 1. Fuel properties of tested fuel blends.

Parameters	Diesel	Cu50	Cu100
Viscosity, 40 ^oC (mm^2/s)	2,745	2,752	2,759
Density, 16 ^oC (Kg/m^3)	837,1	837,5	837,7
Cetane index	54,025	55,342	56,8
Lower heating value (MJ/Kg)	46,27	45,18	45,65
Copper strip corrosion	1A	1A	1A

Engine test system

A four cylinder, direct injection diesel engine was used as a test engine. The engine features were shown in Table 2. The test fuel were tested at full load conditions ranging from 1200 to 3000 rpm at the intervals of 200 rpm. Before initiating the tests, sampling data were collected after the engine had been running for at least 30 min to reach steady state operation temperature. For each combination of parameters, the experiments were performed three times and the results of the three repetitions were averaged. After each fuel test, the engine was operated for at least 15 min. to consume the fuel which was left in the fuel system from the previous test. An electrical dynamometer was used in order to measure the torque and power values. Specifications of the electrical dynamometer are also given in Table 3. Measurement of smoke emission was executed with MRU OPTRANS 1600. MRU DELTA 1600 V gas analyzer was used to measure exhaust emissions. Table 3 shows the characteristics of gas and soot analyzer. A schematic representation of the experimental setup is also shown in Figure 1.

Table 2. Engine specifications

Manufacturer/type	**Mitsubishi Canter/4D34-2A**
Cylinders number	4
Cylinder volume	3907 cc
Bore	104 mm
Stroke	115 mm
Maximum speed	3000 rpm
Maximum power	89 kW at 3200 rpm
Maximum brake torque	295 Nm at 1800 rpm
Injection type	Direct injection
Cooling system	Water-cooled

Table 3. Technical specifications of electrical dynamometer

	Specifications
Maximum torque	350 Nm
Maximum speed	7500 rpm
Torque arm length	350 mm
Total weight	110 kgf

Table 4. Characteristics of gas and soot analyzer

Gas analyzer		**Smoke Meter (Optrans 1600)**	
CO	0-10%	Accuracy	+/- 2 % relative
CO_2	0-20%	Resolution	0,1 %
HC	0-20000 ppm	Ambient temperature	+ 5° C to + 45° C
O2	0-22%	Storage temperature	- 32° C to + 50° C
NO	0-4000 ppm	Sample extraction	partial stream technique
NO_2	0-1000 ppm	Measuring principle	absorption photometry
Lambda	0-9.99		
Accuracy	According to OIML-class 1		
Ambient Temperature	+5o - +45 ^oC		
Exhaust Gas Temperature	Max 650 ^oC		

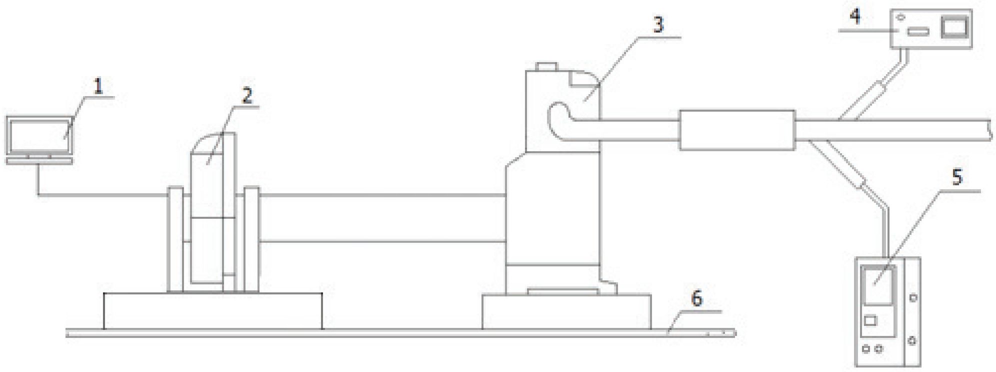

Figure 1. A schematic representation of the experimental setup (1. Control panel, 2. Dynamometer, 3. Test engine, 4. Smoke meter, 5. Diesel emission analyzer, 6. Platform).

RESULTS and DISCUSSION

Test fuels

As can be seen from Table 1, no significant effect on properties like density, viscosity and lower heating value was observed with the addition of copper nitrate nanoparticles into diesel fuel. However, cetane number, viscosity and density values of the blend fuels except for lower heating value were increased slightly with increasing concentration of additives.

Variation of emission values

Variation in HC emission as a function of engine speed is shown in Figure 2. The maximum decreasing ratio of hydrocarbon was found to be 31.57% at 3000 rpm with 50 ppm additive. In general, HC emissions of test fuels with additives showed better results as compared to diesel fuel due to higher evaporation rate and catalytic oxidation. Furthermore, HC emission with 100 ppm additive is much more effective than 50 ppm additive.

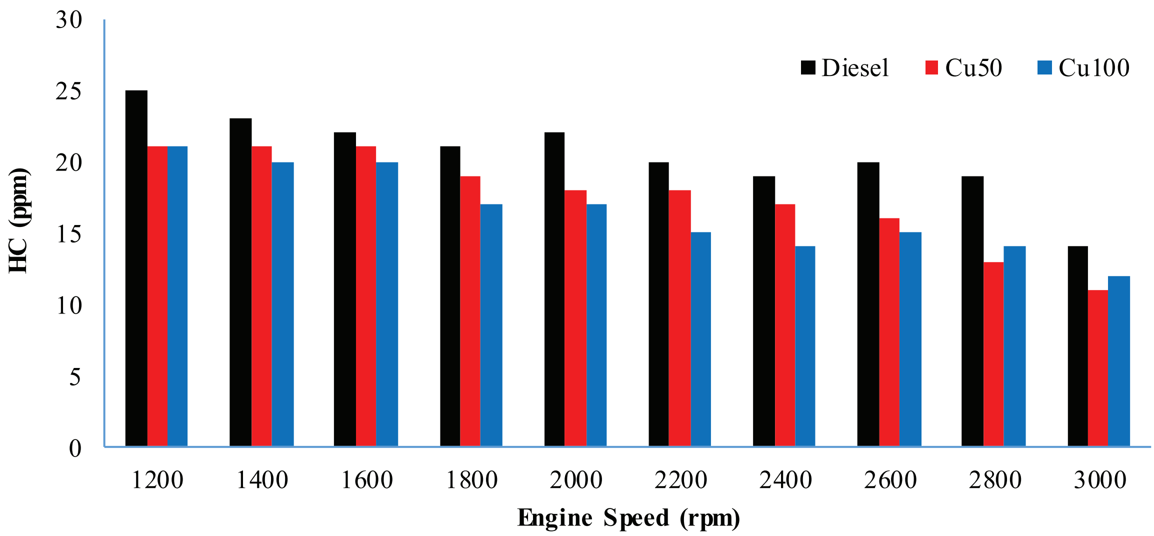

Figure 2. Changes in HC emissions with the blends compared to diesel fuel.

Changes in CO emissions with the blends compared to diesel fuel is shown in Figure 3. CO emissions decreased with copper nitrate additives due to the improved ignition characteristics. Maximum decreasing ratio of carbon monoxide observed is 22.41% at 2800 rpm with 100 ppm additives. At higher engine speeds, the higher CO emission was observed with the increasing of nanoparticles concentration.

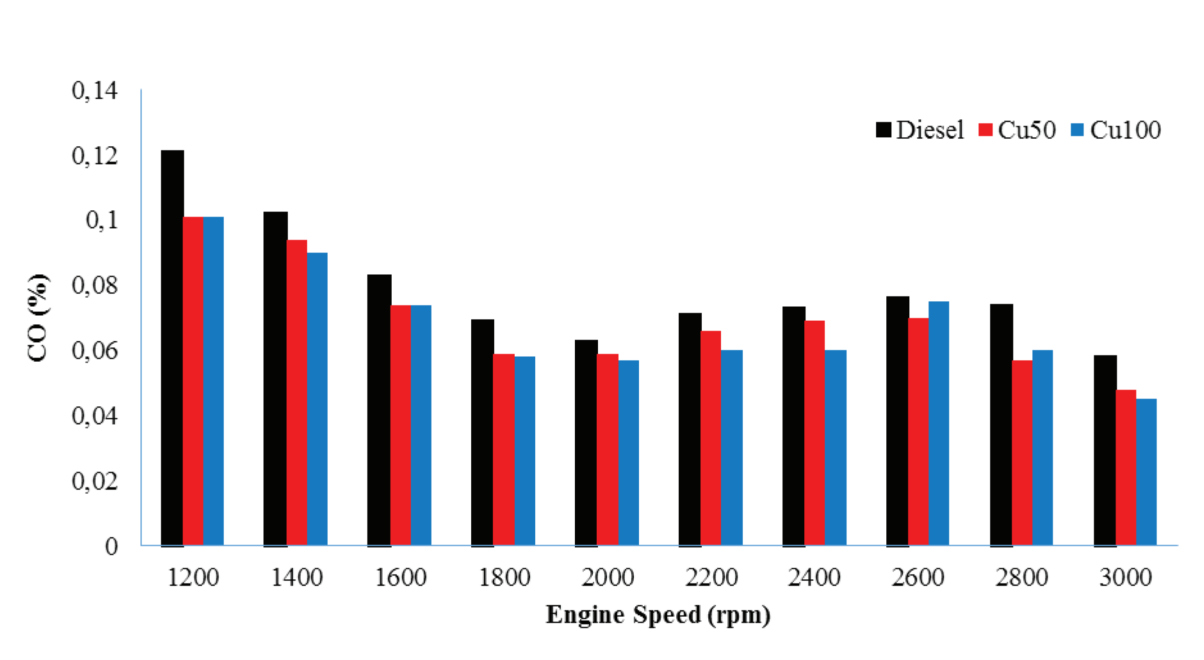

Figure 3. Changes in CO emissions with the blends compared to diesel fuel.

Influence of the blend fuels on NO emissions are shown in Figure 4. The components of NO_x are nitric oxide (NO) and nitrogen dioxide (NO_2) which generated during combustion process. NO emissions are relatively higher with copper nitrate additives compared to neat diesel fuel. When copper nitrate concentration increased, NO emissions increased. The maximum increase of NO emission was observed to be 79.72% with blend fuels at 3000 rpm. This higher NO value is probably because of the copper nitrate additive having more catalyst effect on combustion causing increase in the maximum temperature.

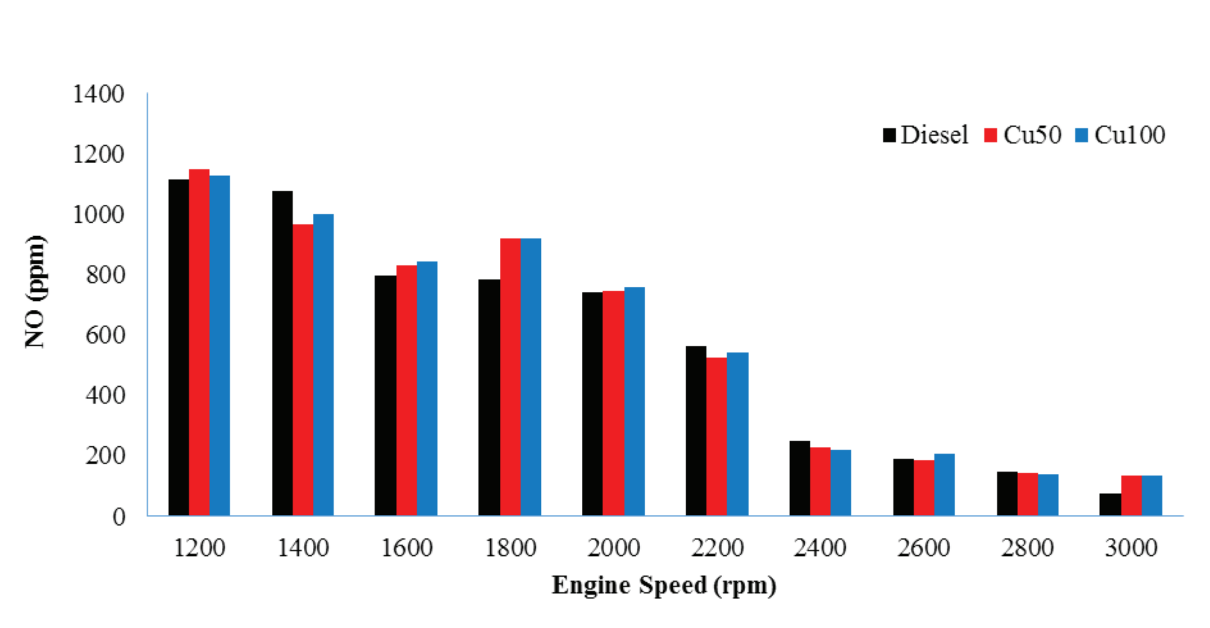

Figure 4. Changes in NO emissions with the blends compared to diesel fuel.

The variations of smoke emission are shown in Figure 5. Tests of smoke emission were carried out with measuring opacity of the exhaust gases. For all engine speeds, low smoke emissions were obtained with the blend fuels in comparison with the diesel fuel. Especially, at higher engine speeds, lower smoke emissions with the blend fuels were observed. The maximum decreasing ratio is 66.86% at 2800 rpm with 50 ppm additives. When evaluated as additive concentration, test fuel with 100 ppm presents the best results in terms of smoke emission. This behavior can be attributed to higher evaporation rate, shorter ignition delay time, and enhanced ignition characteristics.

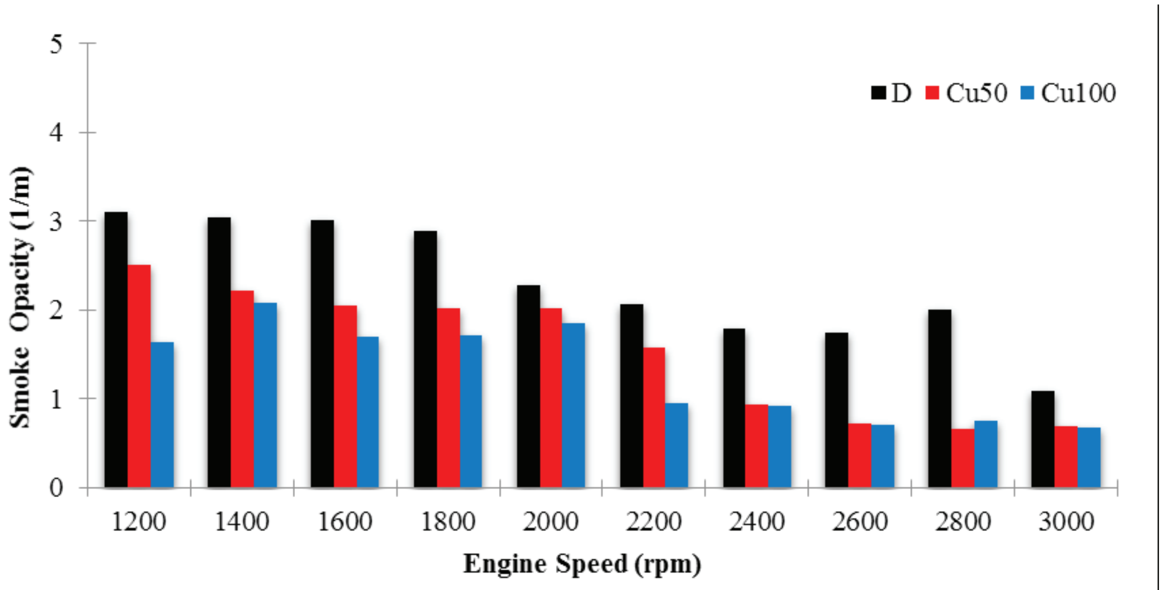

Figure 5. Changes in particulate matter emission with the blends compared to diesel fuel.

CONCLUSIONS

The emission characteristics of a diesel using neat diesel and $CuNO_3$ blended fuels were investigated in order to observe the effect of related nanoparticles as a fuel additive in diesel engine. The dosing of nanoparticles to diesel fuel resulted in higher evaporation rate, shorter ignition delay time, and enhanced ignition characteristics.

Following conclusions can be drawn from the experimental study.

- Addition of $CuNO_3$ additives improved the cetane number of diesel fuel.
- HC emissions of blend fuels with additives showed better results as compared to diesel fuel due to higher evaporation rate and catalytic oxidation.
- At higher engine speeds, the higher CO emission was observed with the increasing of nanoparticles concentration.
- It was observed that NO emissions increased with the increase $CuNO_3$ concentration.
- The dosing of nanoparticles to diesel fuel decreased the smoke emissions.
- It can be concluded that optimum combination of concentration of nanoparticles are needed to study in future.

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