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Review Paper

Exhaust emissions of diesel engine with $CuNO_3$ nano additive and butanol-diesel blends

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Abstract

This experimental study was focused on use of $CuNO_3$ as a fuel additive with butanol-diesel blends in diesel engine and its effects on fuel specifications and emission characteristics. With this purpose, $CuNO_3$ nano additive was mixed with diesel-butanol and each test fuel was analyzed to determine fuel specifications (density, viscosity, Cetane number, heating values and copper strip corrosion). A four stroke, four cylinder direct injection diesel engine was conducted to perform the test fuels. In conclusions, $CuNO_3$ nano additive with diesel-butanol blends improved the fuel specifications and exhaust emission characteristics of diesel engine.

Keywords: $CuNO_3$ nano additive, diesel engine, butanol, exhaust emissions

1. INTRODUCTION

The low fuel consumption, high durability, reliability and performance make diesel engines most preferable compared other internal combustion engines [1]. However, the pollutant emissions especially NO_x and PM from diesel engines have been a serious drawback for diesel engines [2]. Many researchers have studied to prevent the damage of diesel engines reducing the pollutant emissions of diesel engines without any depletion in performance.

The use of fuel additives in diesel engine is an alternative method to prevent the pollutant emissions and improve engine performance [3-4]. Many different fuel additive types (oxygenates, antioxidants (stabilizers), antiknock agents, fuel dyes, metal based additives, corrosion inhibitors) have been used in studies [5]. Especially oxygenates and metal based additives have been much attention by researchers nowadays [6]. Oxygenates and metal based additives improve the engine performance and reduce pollutant emissions in diesel engines. These additives make catalytic effect in combustion reaction and an effective combustion is occurred in combustion chamber [7].

In studies, alcohols (Methanol, Ethanol, Butanol, Propanol, etc.) and biodiesel have been mainly researched as oxygenates additive while Cerium (Cr), Titanium (Ti), Magnesium (Mg), platinum (Pt) , etc. tested as metal based additives [8].

Babu and Anand tested n-pentanol and n-hexanol with diesel-biodiesel blends. They found that the use of n-pentanol and n-hexanol improved performance and emission characteristics of diesel engine [9]. Jiand and et al. added carbon coated aluminium nanoparticles into diesel in terms of different mass ratios. The results showed that carbon coated aluminium was quite conducive to thermal conductivity but had little influence on viscosity. The BSFC of engines decreased up to 13.3% and emissions characteristic of engine increased with nanoparticles [10]. N-butanol and diesel blends were used in a small size, modified, variable compression ratio diesel engine by Nayyar and et al. [11]. N butanol was added in diesel with 10-25% by volume. Engine tests were carried out to see its effects on engine performance and emissions. Results showed that Brake thermal efficiency increased by 5.54% while smoke and nitrogen oxides decreased by 59.56% and 15.96% respectively for B20. Jiaqiang and et al. used Cerium oxide nanoparticle in diesel engine. They found that metal-based additive improved combustion characteristics of engine and decreased the pollutant emissions [12]. Palladium and acetylferrocene was tested as metal based additives in diesel engine by Keskin et al. [13]. CO and PM emissions decreased significantly up to 60.07% and 51.33%, respectively with the use of palladium and acetylferrocene.

This study intends to investigate fuel specifications and emission characteristics of a diesel engine runned by diesel blended with butanol and $CuNO_3$ nano additive.

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2. MATERIAL AND METHODS

2.1 Preparation of blends

Butanol (B) was blended with diesel as a ratio of 5% and 10% volumetrically and $CuNO_3$ nano additive doped in these blends as 50 and 100 ppm. In experimental studies the alcohols rates in fuels have been preferred approximately with the rate of 5-10% by researchers [1]. Four different blends were prepared for engine test to see the effects of butanol and $CuNO_3$ nano additive on fuel specifications and exhaust emission characteristics of diesel engine. Each blend was named according to its rate in blends as B5Cu50, B5Cu100, B10Cu50 and B10Cu100. Test fuels were analyzed at Petroleum Research and Automotive Engineering Laboratories of the Department of Automotive Engineering at Cukurova University.

K 40091 Cinematic Viscosity Meter, A KYOTO DA-130 Portable Digital Density Tester, Zeltex ZX 440 NIR petroleum analyzer, IKA WERKE Bomb Calorimeter and Copper Strip Corrosion Tester were used to determine respectively viscosity, density, Cetane number, lower heating value and copper strip corrosion values of test fuels.

2.2 Experimental setup

The schematic diagram of experimental setup is given in Figure 1. A direct injection, four cylinder, four stroke, water cooled Mitsubishi Canter/4D34-2A diesel engine with a displacement of 3907 cc, 115 mm stroke, 89 kW maximum power at 3200 rpm and 295 Nm maximum torque at 1800 rpm was used in tests. The engine was mounted to a hydraulic dynamometer. MRU OPTRANS 1600 was used to measure Smoke with ± 2% relative accuracy while MRU DELTA 1600 V was used to obtain CO, HC, NO and NO_2 with respectively 0-10%, 0-20000 ppm, 0-4000 ppm and 0-1000 ppm measuring range.

Exhaust emission tests were conducted at full load conditions and engine speeds from 1800-3200 rpm with a constant increment of 200 rpm. Each fuel was tested with three replicates and the averages of results were calculated. The same operating conditions were carried out for all tests.

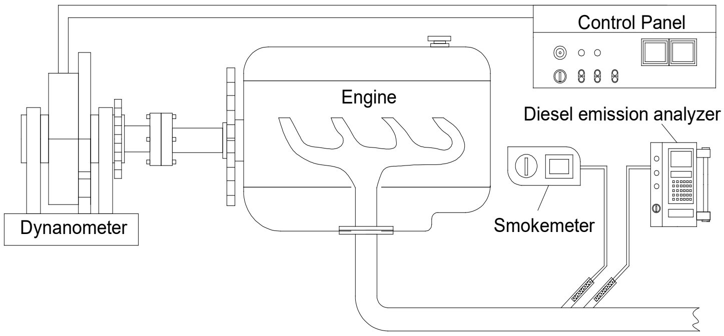

Figure 1: Schematic view of experimental setup

Table 1 The specifications of test fuels

Parameters	Diesel	B	EN590	B5Cu50	B5Cu100	B10Cu50	B10Cu100
Viscosity, 40 °C (mm²/s)	2,745	2,57	2,0-4,5	2,504	2,489	2,429	2,409
Density, 16 °C (kg/m³)	837,1	810	820-845	834,1	834,3	833,1	832,7
Cetane index	54,025	-	Min 51	54,603	55,021	54,738	55,318
Lower heating value (MJ/Kg)	46,27	33	-	46,53	46,91	46,805	47,24
Copper strip corrosion	1A	-	1	1A	1A	1A	1A

3. RESULTS AND DISCUSSION

3.1 The specifications of blends

The specifications of test fuels are represented in Table 1. Use of butanol and $CuNO_3$ nano additive improved the specifications of fuel. Viscosity and density decreased while slight increases were obtained for Cetane index and lower heating value. Copper strip corrosion was determined as 1A for all test fuels. Compared with diesel, maximum decrease in viscosity and density were obtained as 12.24% and 0.52% with B10Cu100. Cetane index and lower heating value were increased as 2.39% and 2.09% with B10Cu100.

3.2 Emission results

Figure 2 shows the comparison of CO between diesel and blends with butanol and $CuNO_3$ nano additive. The use of butanol and $CuNO_3$ nano additive led to significant decrease in CO. Maximum decrease was observed as 31.74% with B10Cu100 at 2000 rpm compared to diesel. Decreases in CO were obtained averagely 12.74% for B5Cu50, 15.71% for B5Cu100, 19.98% for B10Cu50 and 23.84% for B10Cu100. The use of butanol and $CuNO_3$ nano additive in diesel engine improved the combustion efficiency and temperature. Increase in combustion temperature led to burn fuel effectively.

HC emission variations of test fuels are given with Figure 3. Like CO emissions, HC emissions showed downward trend

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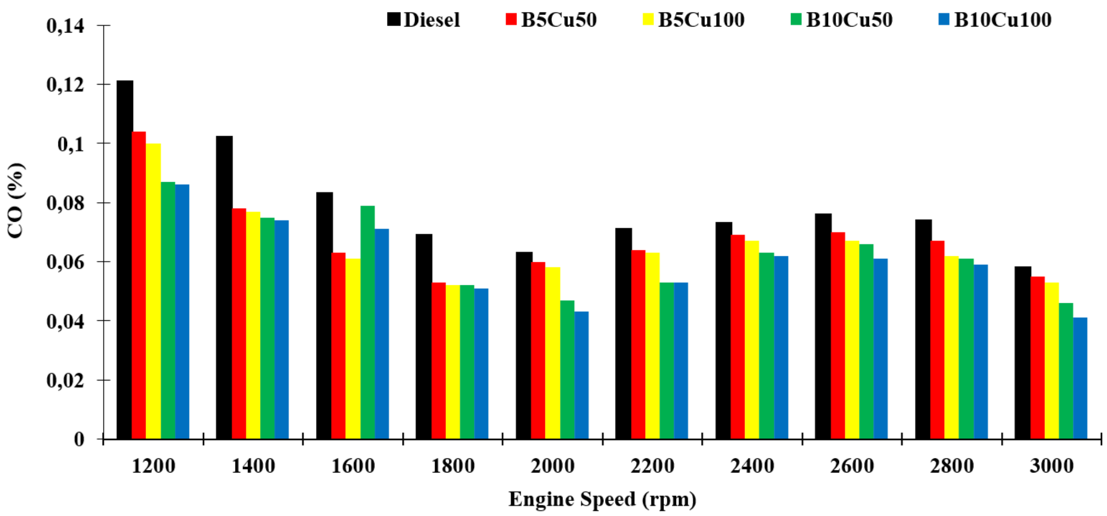

Figure 2: CO emissions at different engine speeds and full load condition

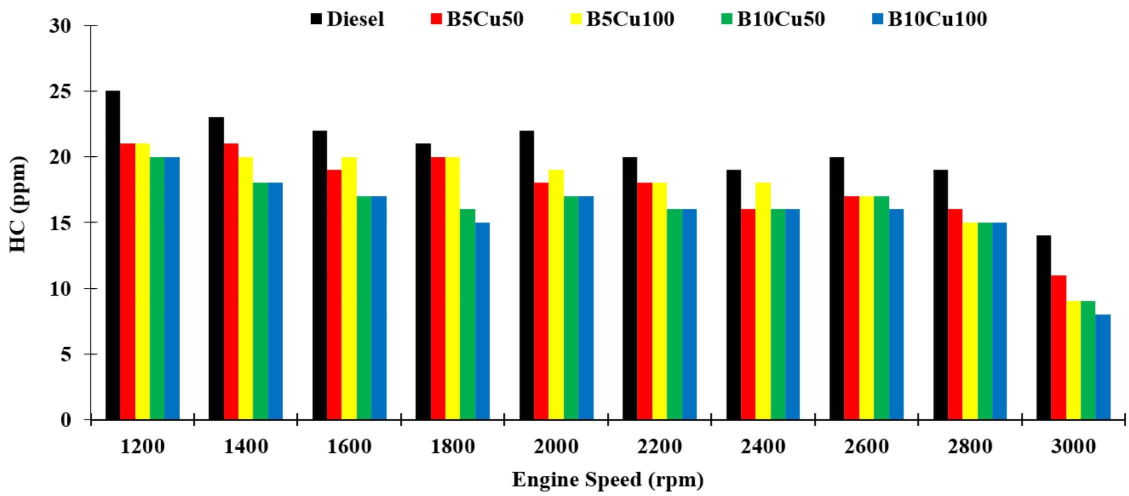

Figure 3: HC emissions at different engine speeds and full load condition

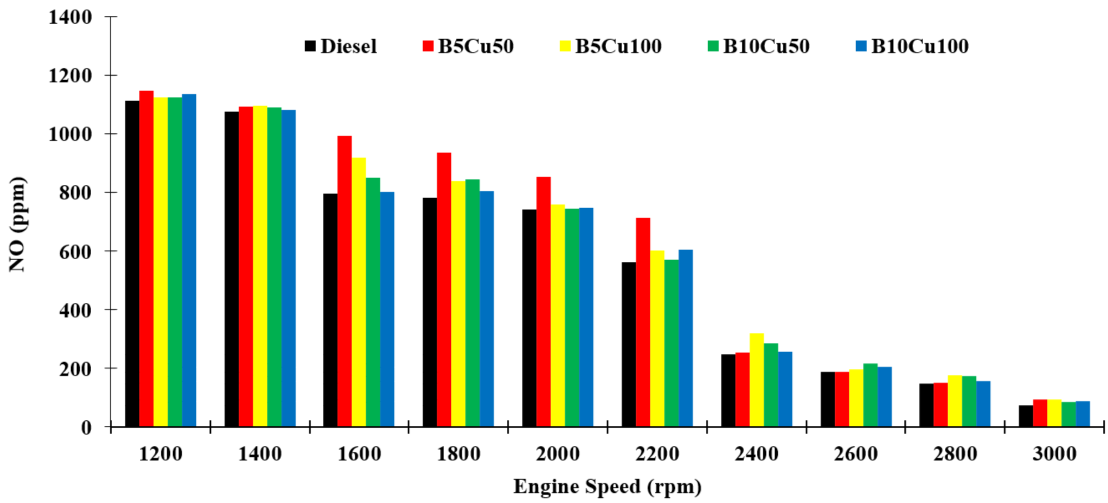

Figure 4: NO emissions at different engine speeds and full load condition

with butanol and $CuNO_3$ nano additive. The experimental results of HC emissions of blends were determined lower at all engine speeds compared to diesel. Maximum decrease in HC emissions was obtained as 42.85% with B10Cu100 at 3000 rpm. The average reduction in HC emissions for B5Cu50, B5Cu100, B10Cu50 and B10Cu100 were obtained as 13.92%, 14.35%, 21.85% and 23.54% respectively. The improvement of combustion efficiency with the use of additives led to significant decrease in HC emissions.

Figure 4 and Figure 5 show respectively NO and NO_2 emission values of test fuels at different engine speeds and full

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load condition. NO and NO_2 emissions increased slightly with blends. Increase rates of NO and NO_2 for B5Cu50 and B5Cu100 was determined higher than those of B10Cu50 and B10Cu100. B10Cu50 and B10Cu100 led to increase averagely 5.04% for NO and 7.55% for NO_2 emission.

Influence of butanol and $CuNO_3$ nano additive on Smoke emissions is given in Figure 6. Significant decreases were obtained in smoke emissions. The use of butanol and $CuNO_3$ nano additive led to decrease averagely as 12.13% for B5Cu50, 27.90% for B5Cu100, 18.33% for B10Cu50 and 32.76% for B10Cu100. Maximum decrease rates were obtained at 2800 rpm for all test fuels.

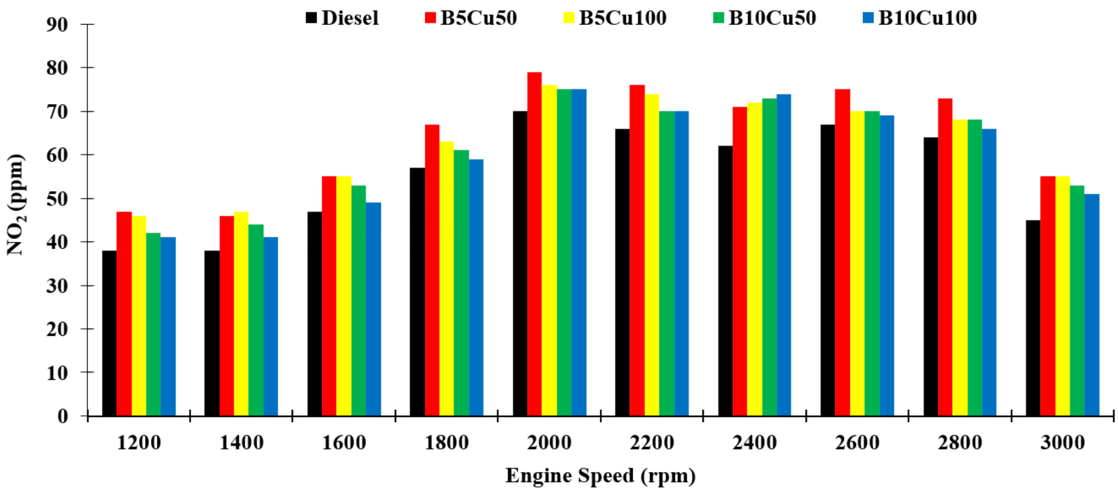

Figure 5: NO_2 emissions at different engine speeds and full load condition

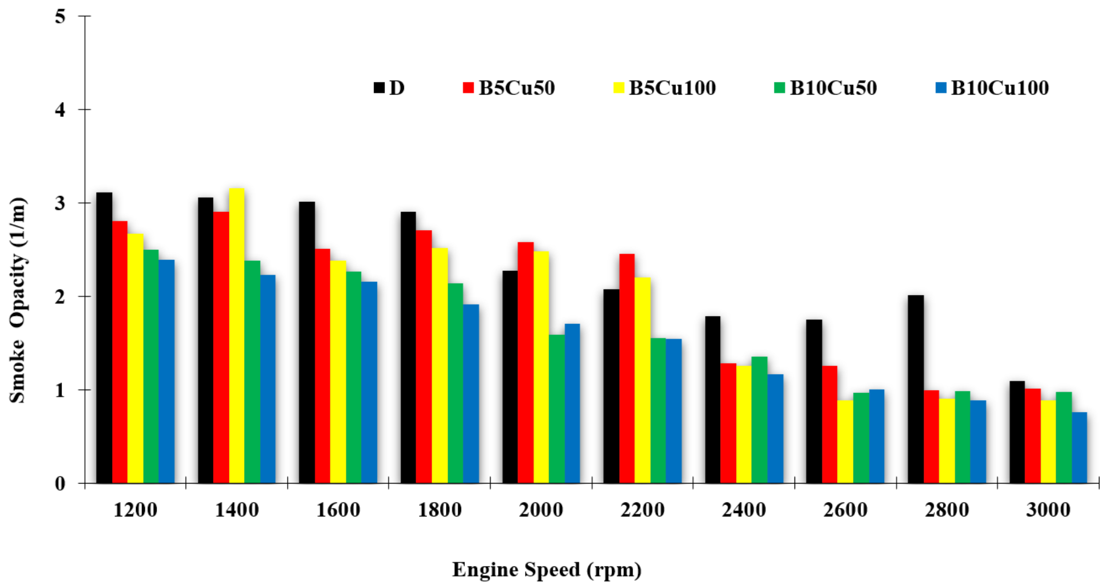

Figure 6: Smoke emissions at different engine speeds and full load condition

5. CONCLUSION

This study focused on butanol and $CuNO_3$ nano additive as fuel additives in diesel engine. Butanol and $CuNO_3$ nano additive were added into diesel and each test fuel was analyzed. Actual engine tests were conducted to see the effects of butanol and $CuNO_3$ nano additive on engine emission characteristics. Results showed that viscosity and density decreased while slight increases were obtained for Cetane index and lower heating value. CO, HC and smoke emissions showed downward trend while NO and NO_2 emissions slightly increased. Consequently, the fuel specifications and engine emission characteristics were improved with the use of butanol and $CuNO_3$ nano additive as fuel additives in diesel engine.

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