STUDYING HOW DIESEL ENGINE ADDITIVES USING SILVER OXIDE (Ag_2O) NANOPARTICLES AFFECT THE ENVIRONMENT

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Abstract: Biodiesel has been defined as an alternative fuel that has the potential to be used instead of diesel fuel for years. In case of complete combustion reaction in engines, the products released do not directly threaten human health. Compared to diesel fuel, biodiesel has worse combustion performance due to some fuel properties. Therefore, incomplete combustion products such as hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NOx), smoke emission and complete combustion products such as CO_2 are thrown into the atmosphere. In this study, the changes in exhaust emissions of 50 ppm and 75 ppm Ag_2O NPs were experimentally examined to improve the adverse combustion performance and emission characteristics of cottonseed oil methyl ester. In experiments, nano additive improved the thermal conductivity, mass dissipation and heat transfer of the test fuels, and resulted in reducing of CO emissions as it provided a higher oxidation rate of hydrocarbon molecules. Due to the improvement in the combustion reaction, CO_2 emission increased with product of complete combustion. The increase in CO_2 emissions was 3.17% and 3.97% for CAg-50 and CAg-75 fuels, respectively, when compared to C0 fuel at 40 Nm load. The NPs additive increased the lower calorific value of the fuel and cylinder temperature. This situation caused increase of NOx emissions by 3.69% and 7.47% CAg-50 and CAg-75 fuels 40 Nm load. Adding of NPs in base fuel reduced to viscosity and density provided better atomization. So a reduction in smoke emission was obtained with NPs addition by 35.09% and 47.32% in CAg-50 and CAg-75 fuels, respectively, compared to C0 fuel at 10 Nm load, while 7.45% and 19.43% at 40 Nm load.

Keywords: exhaust emission, biodiesel, diesel engine, silver oxide (Ag_2O), nanoparticles

Abbreviations

ID	Ignition delay
CP	Cylinder pressure
ICE	Internal combustion engines
CO	Carbon monoxide

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CO_2	Carbon dioxide
NO_X	Nitrogen oxide
HC	Unburned hydrocarbon
NPs	Nano additives
A/F	Air/Fuel
Ag_2O	Silver oxide
CAg-50	Cotton seed methyl ester fuel with 50 ppm Ag_2O nano additive
CAg-75	Cotton seed methyl ester fuel with 50 ppm Ag_2O nano additive

1. INTRODUCTION

Gone are the days when energy alone was the main element of a nation's development needs. Attention has now begun to be paid to more sustainable, environmentally friendly and efficient energy sources. The need for clean energy sources has emerged from the consequences of increasing environmental pollution. Worldwide, the automotive and energy sector is the sector that contributes the most to atmospheric pollution [1]. Diesel engines are seen as the primary sources of environmental pollution global warming [2]. To improve environmental air quality standards, it is necessary to diversify energy from non-renewable fossil-based fuels to renewable energy sources [3]. Due to these environmental disadvantages of diesel fuel, it has been started to be researched that do not accumulate toxic and have low emission values. The most important of these is biodiesel, which is the fuel obtained from plant-derived oils. Also, it is seen as a factor that will provide a balance between environment, agriculture and economic development [4].

The biodiesel was approved by the Environmental Protection Agency as an alternative to petroleum diesel. It is renewable in nature, biodegradable, non-toxic, and also has the ability to reduce majority of pollutants thanks to its clean combustion [5]. Biodiesel simplifies proper combustion by providing additional oxygen leading to increasing of performance and reducing of emissions. It exhibits physicochemical properties very similar to that of pure diesel, and therefore it can be used in diesel engines without any modification [2]. The production method of biodiesel causes to improving of fuel properties and combustion performance. As a result of different production methods and catalyst compositions of biodiesel; fuel properties such as viscosity, density, cetane number and lower calorific value may shows differences [6]. The chemical composition and viscosity of the fuel are most important. Depending on the fuel used, we can observe large variations in ignition delay time, power, torque, exhaust emissions, and even temperature and pressure inside the combustion chamber [7].

The viscosity and density of biodiesel is higher than that of diesel fuel. Recently, nanoparticle additives have been seen as an innovative fuel additive in order to eliminate these disadvantages and improve engine performance and emission characteristics. The using of nanoparticles in engine provides significant advantages in terms of emissions, combustion and fuel properties [8]. Experimental studies such as using nano-sized metallic, non-metallic, organic and mixed particles for diesel fuel appear in the literature. It is seen from results, due to the improvement in the thermophysical and chemical properties of the modified fuel, such as high surface/volume ratio, highly reactive environment for combustion, improved heat and mass transport properties due to high thermal conductivity, improvement in flash point, NPs usage is a promising solution [9]. Although many studies have been carried out on fuel additives, there are still many problems in this area.

Similarly, there are potential environmental hazards with the use of metal oxide and metal nanoparticles. The developing of nanotechnology and usage of its creates interactions between the nanomaterials and environment. They have a positive effect on the performance of different chemical systems. But the releasing of metal oxide nanoparticles into the environment have caused many concerns [10]. In this experimental study, it was aimed to experimentally determine the effect of Ag_2O NPs added into cottonseed oil methyl ester on exhaust emissions without making any changes in the test engine.

2. MATERIAL AND METHOD

In the study, cottonseed oil methyl ester (P0) was produced from cotton oil by transesterification method. The experiments were carried out in the experimental setup in the laboratories of Erciyes University, the schematic of which is shown in Figure 1. In the study, Lombardini LDW 1003 brand engine was used as test engine. The characteristics of test engine are given in Table 1. Nanoparticles in the biodiesel were weighed on an AND-GR200 brand 210 g precision balance with 0.0001 g sensitivity, first with a metallic mixer (Table 2 and Figure 2). Then it was mixed homogeneously into the fuel at 50 ppm and 75 ppm ratios with an ultrasonic mixer for 2 hours at 50ºC. Engine experiments were carried out at a constant speed of 1800 rpm and at 4 different engine loads (10 Nm, 20 Nm, 30 Nm and 40 Nm).

Fig. 1. Experimental setup.

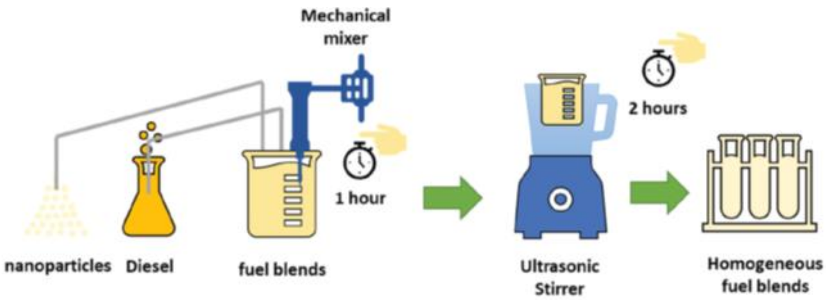

Fig. 2. Preparation steps of nanoparticle + biodiesel fuel mixtures.

Table 1. Technical features of the test engine

Parameters	**Feature**
Brand	Lombardini
Model	LDW 1003
Cylinder number	3
Engine cycle	Four stroke
Maximum engine power	19.5 kW @ 3600 rpm
Maximum engine torque	67.0 Nm @ 2000 rpm
Cooling system	Water cooled
Swept volume	1028 cm^3
Cylinder bore	75.00 mm
Stroke	77.60 mm
Compression rate	22.8:1

Table 2. Properties of test fuels.

	Density (kg/m^3) at 15 °C	**Kinematic viscosity (mm^2/s), at 40°C**	**Flash point (°C)**	**Lower heating value (MJ/kg)**
	ASTM D1298	ASTM D445	ASTM D93	ASTM D240
C100	886	4.6	175	38.80
CAg-50	873	4.5	171	38.84
CAg-75	864	4.3	166	38.90

3. RESULTS AND DISCUSSION

3.1. CO emissions

CO emission formation; It varies as a strong function of the A/F (Air/Fuel) ratio. In order for the CO formed in the intermediate stages of the combustion process to turn into CO_2, there must be sufficient oxygen in the environment for oxidation. Additionally, for CO_2 conversion, sufficient temperature and time are needed for the reaction as well as oxygen. CO emissions are a product of incomplete combustion of HCs that make up fuels, resulting from insufficient O_2 and low oxygen levels for oxidation in the combustion chamber. This emissions occurring towards the end of the combustion process are transformed into CO_2 emissions by combining with different oxidants. Combination reactions that cannot occur due to low combustion chamber temperature and insufficient oxidant level for oxidation trigger an increase in CO emissions. The increase in CO emission values shows that the combustion and performance in the engine is bad. The main reason for the presence of CO among the combustion products is that the fuel cannot be oxidized or semi-oxidized due to the fuel not reaching the ignition temperature or insufficient oxygen in the environment [11].

Figure 3 shows the CO emission graph of the test fuels. In test fuels with NPs additive added, CO emissions decrease with the increase in the additive ratio. While the reduction in CO emissions is greater at low loads, the reduction rate decreases with the increase in load. Because as the speed increased, the end-combustion temperatures also increased and this enabled more CO to be converted into CO_2. The nano additive used in the study contains oxygen. As the cycle progressed, the oxygen contained in the nano additive reacted more with the increase in the end-combustion temperature. This situation contributed to the conversion of CO emissions into CO_2. Compared to CO fuel at 10 Nm load, the reduction in CO emissions was 49.20% and 51.36% for CAg-50 and CAg-75 fuels, respectively, while the reduction rate at 40 Nm load was 9.02% and 28.80%, respectively.

Higher thermal conductivity, mass dissipation and radiant heat transfer by additives results in lower oxidation temperature and higher oxidation rate of hydrocarbon molecules. This caused a decrease in incomplete combustion products such as CO [12].

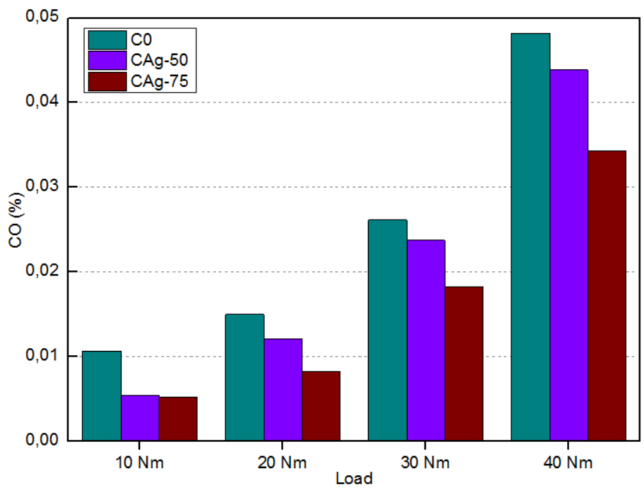

Fig. 3. CO emission graph of test fuels.

3.2. CO_2 emissions

With the burning of fossil fuels, many environmental pollutions accumulate in the atmosphere. CO_2 is formed which causes the problem. The presence of CO_2 in the exhaust products shows complete combustion. The high temperature inside increases the conversion rate of CO to CO_2. As a result, if combustion has occurred well, most of the carbon during combustion turns into dioxide.

Figure 4 shows the graph of CO_2 emissions of test fuels. In fuels which NPs additives are added, viscosity and density decrease depending on additive rate. This situation reduces the droplet size of fuel and improves the fuel-air mix in the cylinder. So it forms better combustion characteristics. The thermal reactivity of the NPs and the increased presence of oxygen in the fuel react with unburned hydrocarbon atoms during the combustion reaction, caused to rising of CO_2 emissions [13]. The increase in CO_2 emissions at 40 Nm load was 3.17% and 3.97% for CAg-50 and CAg-75 fuels, respectively, compared to C0 fuel. Because fuels contain carbon and hydrogen atoms, during combustion, the carbon in the fuel combines with oxygen from the atmosphere to produce CO_2.

The increase in load increases the cylinder wall temperature, thus facilitating better flammability of the fuel in the combustion chamber. This results reduces to CO formation and causes more CO_2 producing [14].

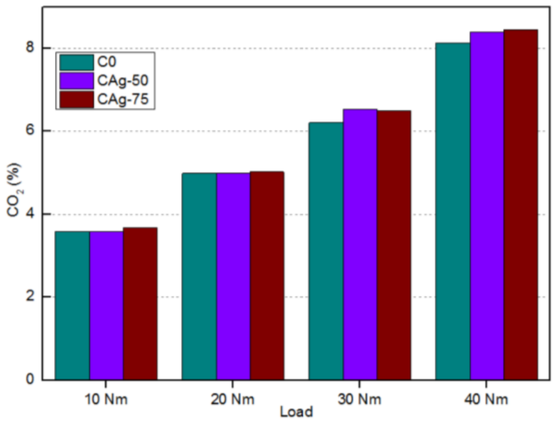

Fig. 4. CO_2 emission graph of test fuels.

3.3. NOx emissions

Approximately 78% of the air content is nitrogen (N_2) gas. This gas does not react in combustion processes under normal conditions and is released as N_2 gas in the products at the end of the combustion process. However, in ICE, as a result of the high temperature reached as a result of combustion following the injection of fuel through injectors in the cylinder, the N_2 gas in the air absorbed into the cylinder during the intake stroke reacts with oxygen molecules and causes undesirable NOx emissions. Nitrogen monoxide (NO) is the main gas that causes the formation of NOx. During the release of this gas into the atmosphere, some of the NO gas turns into nitrogen dioxide (NO_2) and other NOx gases.

There are many factors affecting NOx formation in diesel engines. Among these, in-cylinder gas pressure, heat release rate, reaction temperature, fuel viscosity, density, oxygen content, cetane number, raw material quality of fuel and operating parameters affect NOx emission [11]. NOx emissions are carcinogenic and can cause various diseases in humans in case of continuous exposure [15].

Figure 5 shows the graph of NOx emissions. NOx emission increases depending on the additive ratio. The increase in NOx emissions at 40 Nm load was 3.69% and 7.47% CAg-50 and CAg-75 fuels, respectively according to C0 fuel.

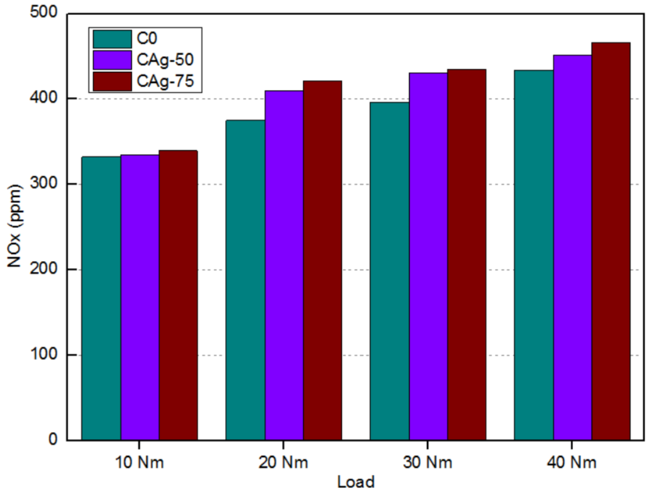

Fig. 5. NOx emission graph of test fuels.

With the increase in load, the cylinder temperature increased, so NOx emission increased with the advance of load. At higher load, more fuel burns and thus a higher temperature forms in combustion chamber [14]. The addition of NPs in to fuel causes to rising of flame temperature. In this way, NOx value of NPs blended fuels are higher than for pure biodiesel in all test conditions [2]. Since the NPs increases the lower calorific value of the fuel, the combustion end temperature increases. The oxygen contained in NPs and the high reaction rate it causes increase the in-cylinder temperature and cause NOx formation [16, 17].

3.4. Smoke emissions

Smoke emissions are an undesirable product of the combustion result in diesel engines. It generally occurs in rich fuel mixture regions. In ICE, the A/F ratio varies depending on engine load. In order obtain efficiently combustion process, there must be a sufficient amount of air and temperature value containing approximately 21% O_2 in the combustion chamber. Because smoke emission formation varies depending on the amount of air, combustion chamber temperature and the time required for combustion to occur. Insufficient air movement at low speeds of compression ignition engines, and at high speeds; Carbon particles cause smoke formation due to reasons such as decreasing volumetric efficiency and insufficient time for combustion.

Figure 6 shows the graph of smoke emissions. It was observed that smoke emissions increased with the increase in load. The reduction in smoke emission in test fuels with NPs added was 35.09% and 47.32% in CAg-50 and CAg-75 fuels, respectively, compared to C0 fuel at 10 Nm load, while 7.45% and 19.43% at 40 Nm load.

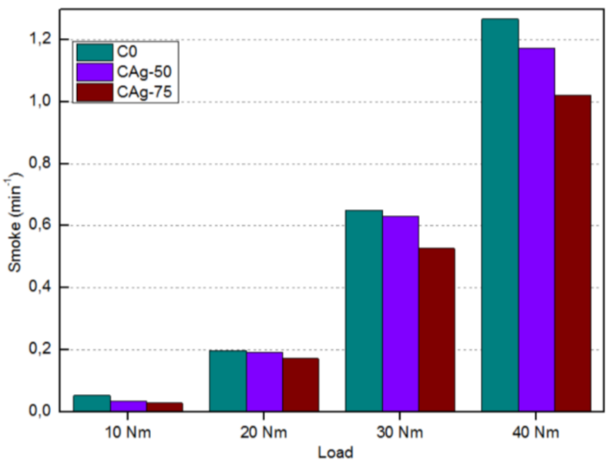

Fig. 6. Smoke emission graph of test fuels.

Adding of NPs in to fuel reduces the viscosity and density of the fuel and helps to improving atomization property. This positively affected the combustion in the cylinder and caused a significant reduction in smoke emissions. NPs shows better heat transfer properties due to the catalytic effect of the additive and reduce smoke emissions by increasing the oxidation of particles at higher temperatures [18].

4. CONCLUSIONS

Combustion process in internal combustion engines takes place in a closed volume and in a very short period of time. Combustion can never be completed in the combustion chamber due to reasons such as heat losses, cold zones on the walls, crevice zones, inhomogeneous filling and insufficient time. In other words, the combustion process is not stoichiometric because stoichiometric combustion conditions cannot be obtained in the cylinder. Under ideal conditions, the combustion products are CO_2, N_2 and H_2O as a result of the theoretical complete combustion of a hydrocarbon-based fuel.

Therefore, many studies are carried out to reduce the pollutants originating from internal combustion engines. One of the methods used to reduce these pollutants is the improvement of fuel properties.

In these studies, the thermophysical properties of fuels are improved by adding NPs in the fuel. In this study, the effect of adding Ag_2O NPs into cottonseed oil biodiesel on the main pollutant exhaust emissions was investigated experimentally. Improvement in fuel properties and superior thermophysical properties of nanoparticles increased the flame rate and the end combustion temperature. This caused CO emissions to turn into CO_2. At 10 Nm load, the reduction in CO emissions was 49.20% and 51.36% for CAg-50 and CAg-75 fuels, respectively, while the reduction rate at 40 Nm load was 9.02% and 28.80%, respectively when compared to C0 fuel. This is the reason for the decrease in CO emissions and the increase in CO_2 emissions in the study.

The study determined that the Ag_2O NPs improved the atomization by reducing the viscosity and density of the test fuels, and this situation caused the increase in the end-combustion temperature. Thus, while NOx emissions increased, smoke emissions decreased. At 40 Nm load the increasing in NOx emissions was 3.69% and 7.47% CAg-50 and CAg-75 fuels, respectively according to C0 fuel. Because of the increase in load, the cylinder temperature also increased; thus, NOx emission increased with the advance of load.

Besides, reduction in smoke emission was 35.09% and 47.32% in CAg-50 and CAg-75 fuels, respectively, compared to C0 fuel at 10 Nm load. It has been observed that this improvement rate in smoke emission decreases as the load increases. It was 7.45% and 19.43% at 40 Nm load. The adding of NPs reduced the droplet size of fuel and improved the fuel-air mix in the cylinder. More carbon turned into dioxide and it was provided better combustion. There were 3.17% and 3.97% higher CO_2 emissions at 40 Nm load for CAg-50 and CAg-75 fuels according to C0 fuel.

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