INVESTIGATION OF THE EFFECTS OF THE ADDITION OF TITANIUM DIOXIDE (T_iO_2) NANOPARTICLE FUEL ADDITIVE IN COTTON BIODIESEL ON ENGINE PERFORMANCE

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Received: 10 October 2023
Revised: 20 December 2023
Accepted: 16 January 2024
Published: 27 May 2024

Abstract: The importance of renewable fuels as an alternative to fossil fuels is increasing due to environmental problems such as the decrease in the reserves of fossil fuels, their presence in certain regions, air pollution and global warming. Two important parameters of biodiesel fuel, which is one of these fuel types, such as high viscosity and density, negatively affect its use. One of the ways to overcome this negative situation is to improve the fuel properties by adding nano fuel additives into biodiesel. In this study, titanium dioxide nano fuel additive was added to biodiesel obtained from cottonseed oil at the rates of 50 ppm and 75 ppm. Specific fuel consumption, brake thermal efficiency and cylinder pressure values, which are the basic performance parameters of the fuel mixtures, were determined in a single cylinder engine at 1800 rpm at 4 different engine loads. According to C100 fuel SFC decreased by 5.03% and 6.29% at 10 Nm load, respectively in CTi-50 and CTi-75 fuels. This improvement rate was 8.73% and 12.58% at 40 Nm load. BTE increased by 8.97% and 13.17% with NPs additives. Thanks to the thermophysical properties of the titanium dioxide fuel additive, the combustion reaction has improved and cylinder pressure increased. It was determined in the study that it positively affected the engine performance and fuel economy.

Keywords: combustion, biodiesel, titanium dioxide (TiO_2), NPs, engine performance

1. INTRODUCTION

Diesel engines work with better fuel efficiency and produce a higher power than a gasoline engine. In industrial uses, diesel engines are very popular due to their durability, robustness and fuel economy. It uses in transportation agriculture and industry sectors [1, 2]. Rising prices of diesel engines and fuels force researchers to develop engines and fuels with better combustion characteristics. In addition, due to the limited oil reserves, efforts are made to obtain maximum energy from fossil fuels [3]. Biodiesel is an important alternative to fossil fuel. It has many benefits and it can be produced from domestic and renewable energy sources. Biodisesl has a favorable burning profile with features such as, high cetane number and low sulfur content when mixed with diesel fuel [4, 5]. One of the most interesting research topics in ICE. Because there is no obligation to make a revizion in the engine in

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https://doi.org/10.29081/jesr.v30i1.003

order to use of thiese alternative fuels. The using of Nps is one of the method to improve combustion and fuel quality of biodiesel [6]. The quality of the burning determines to the torque, fuel economy and pollutant emissions parameters of ICE. Improving of spray properties of fuels in cylinder is the key to optimizing of engine combustion [7]. Many methods are used to improve fuel properties. One of the methods is addition of NPs widely used in recent years. Because NPs have a high surface area and excessive energy of surface atoms. NPs have unique thermal, physical, magnetic, chemical, electrical and optical properties [8]. NPs show an excellent effect in improving engine performance such as engine power, SFC and thermal efficiency [9]. NPs can add to the fuel in very litte rates and readily soluble. Their main aim is improving of fuel spefications and increase combustion performance and oxidation restrictions. Also addition of NPs in biodieses can improve viscosity and density values.Considering the effects of fuel properties, higher viscosity and density make it more difficult for the fuel to evaporate in the cylinder. However, mixing of fuel droplets with ambient air adversely affects the evaporation properties of fuel mixtures. The sprayed fuel droplet is larger because of the higher viscosity and the consequent higher surface tension. Fuel injection quality has a direct impact on engine power, combustion efficiency and emission control. Better atomization quality can promote the mixing of fuel and air and increase the BTE of a diesel engine, providing a full combustion environment [10]. In this study, it was aimed to improve the engine performance parameters without any change in the engine, thanks to the physical and chemical properties of NPs.

2. MATERIAL AND METHOD

In the study, cottonseed oil methyl ester (P0) was produced from cotton oil by transesterification method in a 40 lt capacity reactor. The transesterification reaction was carried out at 60 ºC using 200 mL of methanol and 3.5 g of alkaline catalyst (NaOH) for 1 liter of oil in biodiesel production. Engine tests were carried out in the experimental setup shown in Figure 1. In the study, Lombardini LDW 1003 brand engine was used as the test engine. The characteristics of test engine are given in Table 1. The NPs mixed homogeneously into biodiesel with ultrasonic mixer which was shown in Figure 2, for 45 minutes at 50 ºC. It was AND-GR200 brand, 210 g capacity and 0.0001 g precision balance. The properties of the obtained fuel blends are given in Table 2. Bosch BEA60 and Bosch BEA70 model exhaust emission measuring devices were used to measure exhaust emissions. The experiments were carried out at 1800 rpm at 4 different engine loads.

Fig. 1. Experimental setup.

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
Powertrain	Single overhead camshaft, full overhead controlling system
Valve system	2 valves per cylinder
Type of fuel injection	Pump/injector unit - direct injection
Ignition	Compression-ignition
Cooling system	Water cooled
Aspiration	Naturally-aspirated
Swept volume	1028 cm^3
Cylinder bore	75.00 mm
Stroke	77.60 mm
Compression rate	22.8:1

Fig. 2. Ultrasonic mixer and fuel with NPs.

Table 2. Properties of test fuels.

	Density (kg/m^3) at 15 °C	**Kinematic viscosity (mm^2/s), at 40°C**	**Flash point (°C)**	**LHV (MJ/kg)**
	ASTM D1298	ASTM D445	ASTM D93	ASTM D240
C100	886	4.6	175	38.80
CTi-50	859	4.2	165	39.01
CTi-75	846	4.0	152	39.22

3. RESULTS AND DISCUSSION

3.1. Specific fuel consumption

SFC in diesel engines is related to the fuel spray characteristic, density and viscosity of fuel and lower calorific value [11]. Many studies show that the fuel consumption values of biodiesel is higher than diesel fuel. This is due to low calorific value, high density and viscosity. The thermophysical characteristics of the fuels is very important in terms of fuel consumption [12]. Figure 3 shows the SFC graph of the test fuels. SFC at 10 Nm load decreased by 5.03% and 6.29%, respectively, in CTi-50 and CTi-75 fuels with NPs, compared to C100 fuel, while this decrease was 8.73% and 12.58% at 40 Nm load. It was seen that density and viscosity of the fuels with nanoparticle additives decreased, while the lower calorific value increased. The low viscosity and density cause better atomization of the fuel. This ensures better combustion and lower fuel consumption in the reaction zone. Besides, NPs additives have larger active surface area and improve heat transfer between unburned fuel particles with front flame thanks to higher thermal conductivity. This stuation provides better combustion of fuel, thus fuel consumption reduces [3].

3.2. Brake thermal efficiency

Figure 4 shows BTE graph of tests fuels. In cotton biodiesel (C100), BTE was 21% at 10 Nm load and 36% at 40 Nm load. It is shown that BTE improves with the increasing load. Compared to C100 fuel at 40 Nm load, BTE of fuels with added NPs additives increased by 8.97% and 13.17% in CTi-50 and CTi-75 fuels, respectively. BTE is inversely proportional to the SFC and the lower calorific value. With the addition of NPs additive to the fuel, the lower heating value increases and accordingly a change in thermal efficiency occurs. High viscosity and density cause the formation of larger droplets during the injection of the fuel and its insufficient mixing with air by evaporation. Fuel additives increase BTE as they will help the more quickly fuel evaporation. The high thermal efficiency is thought to be due to less heat losses at lower temperatures at the start of combustion. The catalyst effect resulting from the low oxidation energy of the additives reduces the oxidation heat of the fuel molecules and improves the BTE [13].

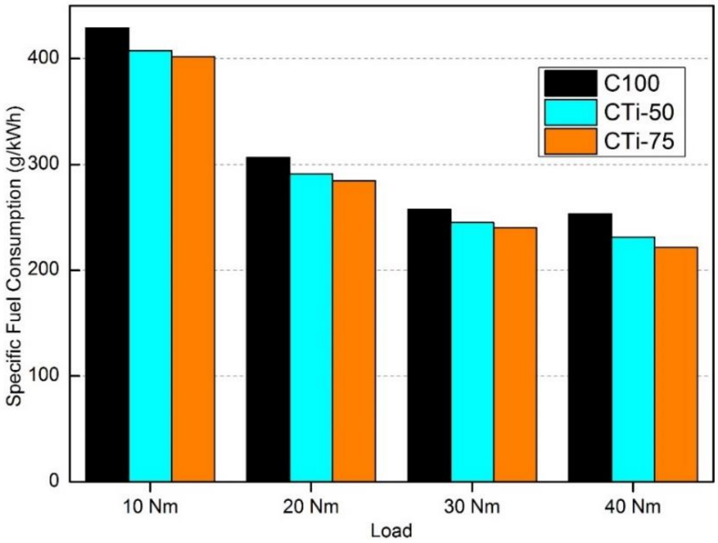

Fig. 3. SFC graph of test fuels.

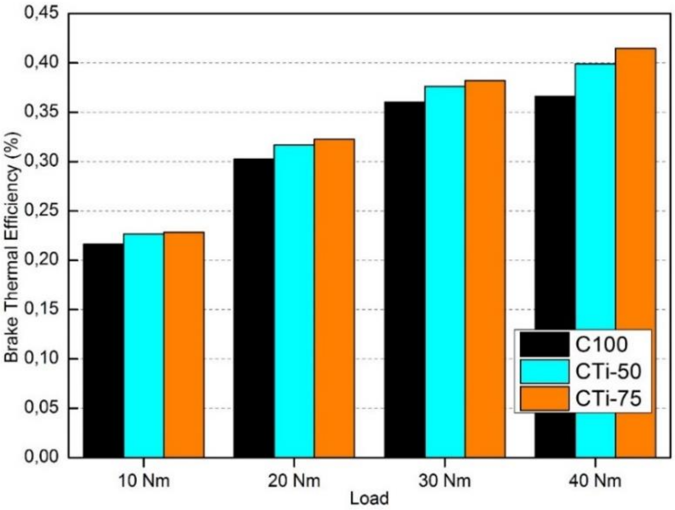

Fig. 4. Thermal efficiency graph of test fuels.

3.3. Cylinder pressure

The cylinder pressure is one of the most important indicators for measuring combustion quality [14]. The purpose of the combustion process is to convert the chemical energy to heat energy which can then be converted into useful torque and power. In order for fuel combustion to be as complete as practically possible, air exceeding the stoichiometric amount is needed. In a diesel engine, the maximum cylinder pressure depends on the amount of fuel involved in the uncontrolled combustion process, which is controlled by the ignition delay time, and the spray structure formed during the fuel injection process. Due to the decrease in viscosity, fuel mixes better with air and causes high cylinder pressure [10]. Cylinder gas pressure; it varies depending on engine load, engine speed, amount of fuel sprayed during the ignition delay, cetane number, viscosity, density, spraying and atomization of the fuel [15, 16]. It also characterizes the ability of the injected fuel to mix with air [17]. Figures 5-8 shows the cylinder pressure graph of the test fuels.

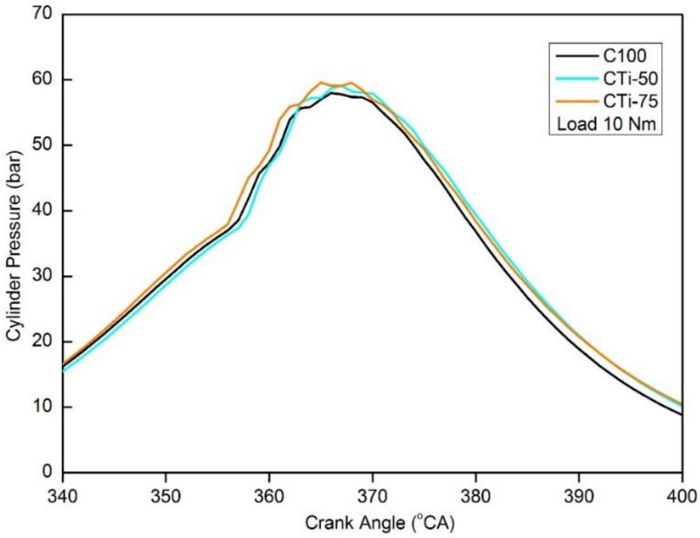

Fig. 5. CP graph of test fuels (10 Nm).

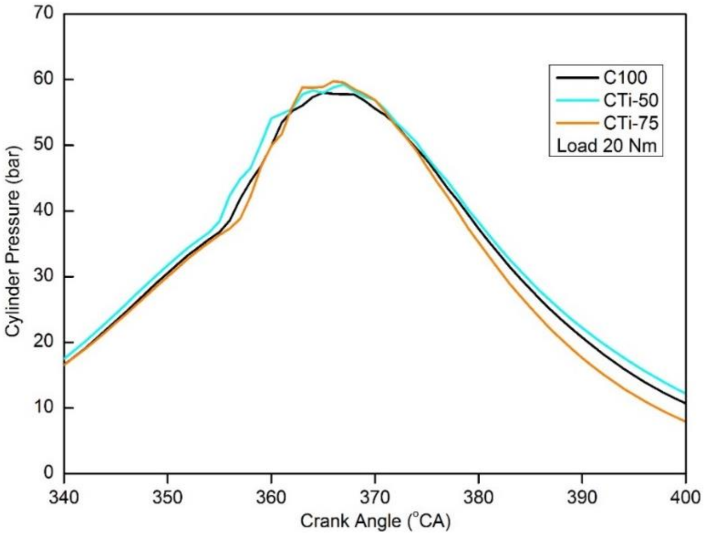

Fig. 6. CP graph of test fuels (20 Nm).

It was observed that the cylinder pressure in C100 fuel at 10 Nm load was 57.97 bar, while at 40 Nm load it was 58.21 bar. As the load increases, the cylinder pressure also increases. As the NPs additive ratio increased in the test fuels, the cylinder pressure also increased. It was observed that the cylinder pressure in CTi-75 fuel at 40 Nm load was 60.80 bar. Thanks to the improved cetane number, lower viscosity and density better atomization feature of fuels was obtained with NPs additive. NPs have higher surface area, heat transfer rate and excellent physical-chemical properties, the size of the fuel droplet decreases and the evaporation rate increases, resulting in a better fuel-air mixture and a better combustion process resulting in a shortening of the ignition delay. As a result, maximum cylinder pressure and temperatures increase [18-19]. In addition, cylinder pressure increased due to the improved burning rate of nanoparticle-added fuels and improved evaporation of fuel droplets [20]. During fuel combustion, the nanoparticle provides a potential catalyst, increasing cylinder pressure [21].

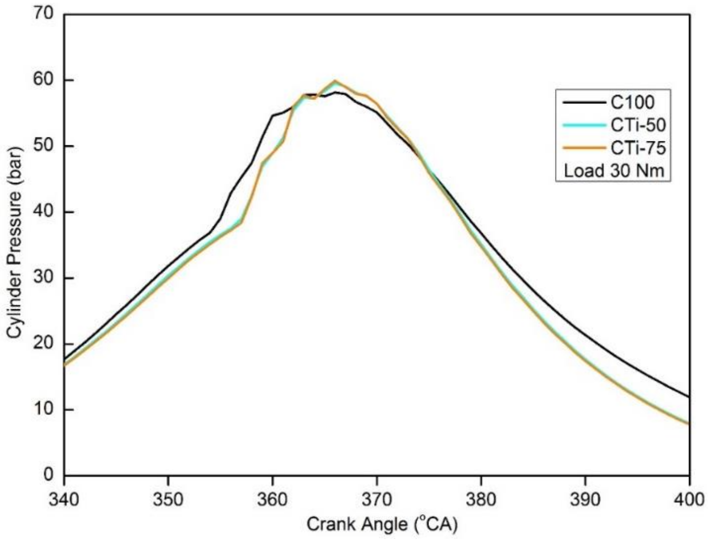

Fig. 7. CP graph of test fuels (30 Nm).

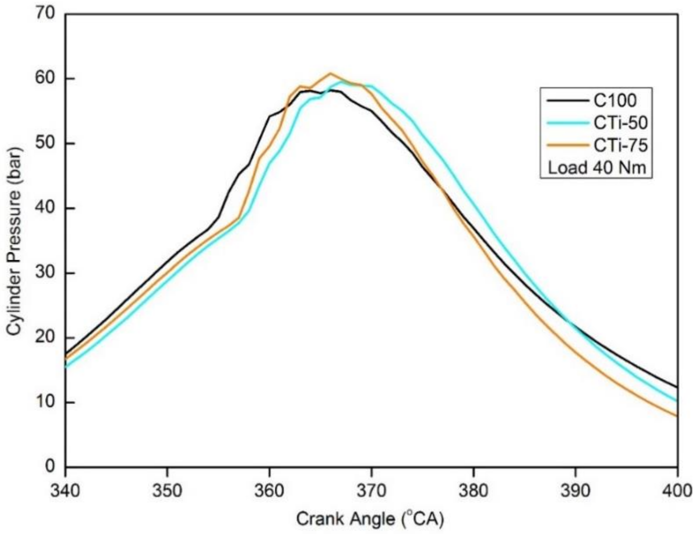

Fig. 8. CP graph of test fuels (40 Nm).

4. CONCLUSIONS

In this experimental study, titanium dioxide nano additive was added to cottonseed oil methyl ester in order to optimize fuel properties. The improvement of density and kinematic viscosity the of fuel mixtures improved the engine performance parameters by adding titanium dioxide nano additive. SFC was decreased between the rates of 5.03%-6.29% at 10 Nm load in CTi-50 CTi-75 fuels respectively when compared to C100 fuel. The reduction rate was 8.73% and 12.58% at 40 Nm load. It is observed that BTE increases with the increasing of engine load. At 40 Nm load, thermal efficiency increased by 8.97% and 13.17% in CTi-50 and CTi-75 fuels, respectively. The cylinder pressure was 57.97 bar in C100 fuel at 10 Nm load, it was calculated as 58.21 bar at 40 Nm load. It was observed that the CP was 60.80 bar at 40 Nm load for CTi-75 fuel.

Thanks to NPs additive in fuels, cetane number increased. It is result from titanium dioxide nano additive have large surface area, better heat transfer rate. So CP increased with the excellent physical-chemical properties of TiO_2 NPs. This study presented that titanium dioxide improves the fuel properties and increases the performance of biodiesel fuels, which cannot be used much due to the high viscosity problem, so it may have an important fuel additive potential.

Abbreviations

BSFC	Brake specific fuel consumption
BSEC	Brake specific energy consumption
HRR	Heat release rate
CP	Cylinder pressure
LHV	Lower heating value
BTE	Brake thermal efficiency
ID	Ignition delay
CP	Cylinder pressure
CIE	Compression ignition engines
SFC	Specific Fuel Consumption
CO	Carbon monoxide
CO_2	Carbon dioxide
NOX	Nitrogen oxide
HC	Unburned hydrocarbon
NPs	Nano additives
ICE	Internal combustion engine
CTi-50	Cotton seed methyl ester fuel with 50 ppm T_iO_2 additive
CTi-75	Cotton seed methyl ester fuel with 50 ppm T_iO_2 additive

Acknowledgment

This study was supported by Research Projects Coordination Unit of Nigde Omer Halisdemir University with ref. number FMT-2020/1 BAGEP. The authors thank to Research Projects Coordination Unit of Nigde Omer Halisdemir University for their supports.

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