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Research Article

Effect of Diesel-Biodiesel-Methanol Blends on Performance and Combustion Characteristics of Diesel Engine

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ABSTRACT

Due to the increase in fossil fuel prices, limited reserves and environmental damage, researchers turned to renewable energy sources. Studies have been conducted on the use of biodiesel to reduce the use of fossil fuels used in vehicles. In this study, biodiesel obtained from cottonseed oil by transesterification method was used as fuel. Cotton oil methyl ester and methanol, different proportions of fuels (diesel fuel (DF), 20% biodiesel (BD20) by volume, 20% methanol (AL20) and derivatives (BD20AL20) were obtained. The effects of DF and other fuels on the combustion and performance characteristics were discussed. The tests were conducted on a single-cylinder diesel engine at the varying engine speeds from 1750 to 3250 rpm with the intervals of 500 rpm. In comparison with that of conventional DF, the BSFC value of BD20, BD20AL20, and AL20 test fuels has exhibited a significant increment with 10.4%, 39%, and 24%, respectively. DF has the highest value with 28.93% BTE. The reason of the high BTE for DF is the heating value, and high-energy content thereof. In comparison with that of DF, the BTE value of BD20, BD20AL20, and AL20 test fuels has exhibited a significant decrease with 6.8%, 16.74% and 9.5%, respectively. Maximum in-cylinder pressure and maximum heat release rate values are observed for the test fuels containing biofuels due to their low cetane number as compared to that of DF.

Keywords: *Diesel engine, Methanol, Cottonseed oil methyl ester, Performance, Combustion, Ternary blends*

Dizel-Biyodizel-Metanol Karışımlarının Dizel Motorun Performans ve Yanma Özelliklerine Etkisi

ÖZET

Fosil yakıt fiyatlarındaki artış, sınırlı rezervler ve çevresel hasar nedeniyle araştırmacılar yenilenebilir enerji kaynaklarına yöneldiler. Taşıtlarda kullanılan fosil yakıtların kullanımını azaltmak için biyodizel kullanımı üzerine çalışmalar yapılmıştır. Bu çalışmada, transesterifikasyon yöntemi ile pamuk tohumu yağından elde edilen biyodizel yakıt olarak kullanılmıştır. Pamuk yağı metil ester ve metanol, farklı oranlarda yakıtlar (dizel yakıt (DF), hacimce %20 biyodizel (BD20), hacimce %20 metanol (AL20) ve türevlerinin üçlü tipi (BD20AL20) elde edildi. DF ve diğer yakıtların yanma ve performans özelliklerine etkileri tartışıldı. Testler, tek silindirli bir dizel motor üzerinde, 1750 ile 3250 rpm arasında değişen motor hızlarında, 500 rpm aralıklarla gerçekleştirildi. Geleneksel DF ile karşılaştırıldığında BD20, BD20AL20 ve AL20 test yakıtlarının BSFC değeri sırasıyla % 10,4,% 39 ve% 24 ile önemli bir artış göstermiştir. DF %28,93 BTE değeri ile en yüksek değere sahiptir. DF için yüksek BTE'nin nedeni, ısıtma değeri ve bunun yüksek enerji içeriğidir. DF ile karşılaştırıldığında BD20, BD20AL20 ve AL20 yakıtlarının BTE değeri sırasıyla %6,8, %16,74 ve %9,5 ile önemli bir düşüş göstermiştir.

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Biyoyakıt içeren test yakıtlarında, setan sayısının DF'ye göre düşük olması nedeniyle maksimum silindir içi basınç ve maksimum ısı salım hızı değerleri gözlenmektedir.

Anahtar Kelimeler: *Dizel motor, Metanol, Pamuk yağı metil esteri, Performans, Yanma, Üçlü karışımlar*

I. INTRODUCTION

Due to the recent increase in the prices of fossil fuels, the decrease in its reserves, and the damage it has caused to the environment, it has led researchers to work on alternative energy sources [1] [2]. These sources are energy sources such as biomass, hydrogen, solar energy, and wind energy. Biomass is seen to be more advantageous than other sources. Because biomass is an application where plants collect and store solar energy through photosynthesis [3]. Environmental fuels have become more important due to the increased risk of global warming in recent years. In this respect, they have a great advantage with biodiesel. Biodiesel is obtained by applying different methods from vegetable oils. It is a product obtained by mixing biodiesel organic oils with base and alcohol and converting them into DF. Biodiesel is obtained by separating glycerol from vegetable oil. As a result of this process, two products remain. These are esters and glycerol [4].

The rapid increase in the number of motor vehicles increases the amount of fuel these vehicles consume. Therefore, the researchers aimed to find an alternative fuel without making any changes to the vehicles [5]. One of these important studies is to obtain biodiesel from vegetable oils. As an alternative to DF, sesame oil, soybean oil, canola oil, cotton oil, and corn oil are vegetable oils used in making biodiesel [6]. Biodiesel is a safe fuel as it has a high temperature of exacerbation. In case of any spill, it does not pose a risk to water and soil and pollutes less. Free from sulfur and aromatic hydrocarbons, contains around 11% oxygen [7].

In the literature, it has been observed that there are studies by adding different proportions of alcohol to biodiesel fuels. Alcohols are usually obtained from products that contain sugar and starch. The raw material is fermented with pure yeast and by-distillation is removed from alcohol (rectification and dehydration), leaving alcohol alone. The use of alcohol in internal combustion engines (ICEs) dates back to a century. Especially the use of alcohol in light cars is not new; however, it started to attract worldwide attention. Alcohol such as ethanol, butanol, methanol, fusel oil, and ether are used as fuel in ICEs [8]. There are many studies on the effects of fuels, alcohols, and blends of biodiesel on engine performance and combustion.

Usta et al., produced biodiesel from the hazelnut oil/waste sunflower blend using sodium hydroxide (NaOH), sulfuric acid (H_2SO_4), and methanol. The effects of adding methyl ester to DF on the performance and emissions of a four-stroke, four-cylinder, indirect injection diesel engine, both partial and full load, were investigated. Biodiesel blends produced slightly higher power and torque than DF at full load and partial loads. The 17.5% biodiesel blend has been shown to provide maximum power and thermal efficiency [9]. Yılmaz compared the standard DF, B45M10 (45% biodiesel, 10% methanol, 45% diesel), B40M20 (40% biodiesel, 20% methanol, 40% diesel), B45E10 (45% biodiesel, 10% ethanol, 45% diesel) and B40E20 (40% biodiesel, 20% ethanol, 40% diesel) blends to the effect of methanol and ethanol on a two-cylinder four-stroke diesel engine at full load under the same operating conditions. As the alcohol concentrations of the blends increased, nitric oxide (NO) emissions decreased and carbon monoxide (CO) and hydrocarbons (HC) emissions increased. It was also determined that methanol blends are better than ethanol blends to reduce CO and HC emissions, and that ethanol blends are effective in reducing NO [10]. Rizwanul Fattah et al. used potassium oxide (KOH) as a catalyst for palm biodiesel and formed a blend with the addition of two antioxidants. The effects of B20 and antioxidant added B20 blends on emission and engine performance were investigated. A diesel engine was tested at constant load and variable engine speeds. Both antioxidants reduced nitrogen oxides (NO_x) by 9.8-12.6% on average compared to B20. Besides, compared to antioxidant blends B20, average increases in CO and HC emissions were observed at 8.6-12.3% and 9.1-12.0%, respectively [11]. Yılmaz et al. examined the effects of standard diesel (D100), biodiesel

(B100), and biodiesel-butanol blends (B95Bu5, B90Bu10, B80Bu20) on emission and engine performance in a diesel engine. Fuels with butanol blended showed lower CO and HC emissions compared to biodiesel, while lower exhaust gas temperatures and NO_x emissions were obtained. Butanol blended fuels achieved lower CO and higher NO_x emissions than DF at low concentrations, but no significant changes in HC emissions were identified [12] Liu et al. investigated the effect of different alcohol substances in biodiesel fuel on combustion in the diesel engine. In the experiments, B20S80 (20% butanol and 80% soybean biodiesel) and E20S80 (20% ethanol and 80% soybean biodiesel) were used as blends. As a result, E20S80 fuel showed higher peak pressure and shorter combustion time compared to B20S80 fuel [13]. Can et al. performed performance and emission analysis on a diesel engine by adding ethanol in DF at different rates. Experiments were carried out at different pressures and full load. Better performance was observed as the pressure was increased in ethanol blends [14]. Özener et al. reviewed the combustion, emission and performance characteristics of biodiesel produced from soybean oil, and blends in the diesel engine. Experiments were tested in a single-cylinder direct injection diesel engine at 1200-3000 rpm. Combustion analysis has shown that the addition of biodiesel to conventional DF reduces ignition delay and reduces premixed peak [15]. Yusri et al. investigated the effect of combustion and emission in a diesel engine by adding different amounts of butanol to DF. In the experiments, DBu5, DBu10 and DBu15 were used as fuel (5%, 10%, and 15%). Combustion analysis results showed that butanol/diesel blends had a lower in-cylinder pressure (CP), pressure increase rate, and heat release rate (HRR) [16]. Keskin investigated the effects of cotton oil biodiesel on combustion, engine performance, and emissions by adding DF in different ratios (B10, B20, and B50). Experiments were carried out at full load between 1500 rpm and 3000 rpm at 500 rpm intervals. It was determined that the addition of biodiesel caused a decrease in engine power and torque at all engine speeds. Besides, it was determined that CO, HC, and soot emissions decreased and NO_x emissions increased. It has been observed that the ignition delay time of biodiesel is high, it increases the HRR rapidly and shortens the burning time [17]. Öztürk et al. used canola oil ester and B0, B50 fuels as biodiesel. As a result of the experiment, it has been determined that biodiesel reduces CO_2 emissions by 4.2% and blend fuel by 2.8% compared to diesel. On the other hand, NO_x emission gave almost the same results as diesel [18]. Qi et al. examined the effects of diethyl ester and ethanol-biodiesel-diesel blends on emissions of a diesel engine. Test fuels were determined as B30 (30% biodiesel), BE-1 (5% diethyl ether, 25% biodiesel and 70% diesel) and BE-2 (5% ethanol, 25% biodiesel and 70% diesel). NOx emissions determined higher for BE-2. It was observed that HC emissions are higher for BE-1 and BE-2 but lower CO emissions. It was stated that BE-1 gives better performance and burning characteristics than BE-2 and B30 [19]. Kim et al. obtained the biodiesel and bioethanol blends and investigated the effect of emissions in a diesel engine on the size of the particles. It is stated that the biodiesel-diesel blend reduces HC and CO emissions. In the bioethanol-diesel blend, smoke emission was found to decrease by 50%. The use of biodiesel and bioethanol (BD15E5) fuel has been reported to be much more effective in reducing particle count and particle mass compared to using BD20 fuel [20]. Labeckas et al. used E5, E10 and E15, and E15B5 fuels in a four-cylinder, naturally aspirated diesel engine. While adding ethanol to DF reduces NO_x and HC emissions, they determined that the effect of a higher ethanol mass content on CO emissions and smoke darkness depends on the air-fuel ratio and engine speed [21]. Şimşek et al. added two different proportions (10%, 20%) of propanol alcohol to the biodiesel and tested it in a single-cylinder diesel engine. The results obtained indicate that the addition of alcohol increases engine performance, decreases CO, NO_x, and soot emissions, and increases HC emissions compared to biodiesel fuel. It was determined that propanol added to biodiesel eliminates some disadvantages of biodiesel and provides a significant reduction in NO_x emission [22].

In the literature review and considering the characteristics of the engine used, the engine speed that gives the highest torque value is accepted as around 2400 rpm. In the study, the best burning situation was tried to be achieved by scanning around this period. Load and fuel condition have been chosen as the comparable values by evaluating the literature studies. When the studies conducted in general are examined, it is seen that there is a decrease in engine torque and engine power values and an increase in fuel consumption in diesel-biodiesel blends. In order to eliminate these disadvantages of biodiesel, methanol has been added to achieve values that are closer to standard diesel fuel in terms of performance and fuel consumption. In this study, the effects of cottonseed methyl ester, DF, and methanol blends on the performance and combustion of a single cylinder air cooled diesel engine were tested at full load and different engine speeds.

II. MATERIAL AND METHOD

A. PREPARATION OF BIODIESEL

In this study, biodiesel was produced by applying the transesterification method to refined cottonseed oil. NaOH was used as the catalyst and 20% by volume of methanol was used in DF. NaOH was added to 3.5 g/L of methanol. Then, NaOH and methanol were then mixed at 30 °C. Besides, refined cotton oil seeds were kept at 60 °C. After this process, heated cottonseed oil, NaOH and methanol were mixed for 60 minutes. Then the reaction occurs and glycerol is separated from cottonseed oil. The production steps of biodiesel are shown in Figure 1.

After the biodiesel and glycerol were separated, the washing process was applied to the blend. By the water washing process, it is intended to separate methanol, catalyst, soap, salts, or free glycerol remaining in the biodiesel obtained. Finally, the blend is exposed to about 110 °C to separate these materials. Some specifications of cottonseed oil methyl ester, diesel, and methanol are given in Table 1.

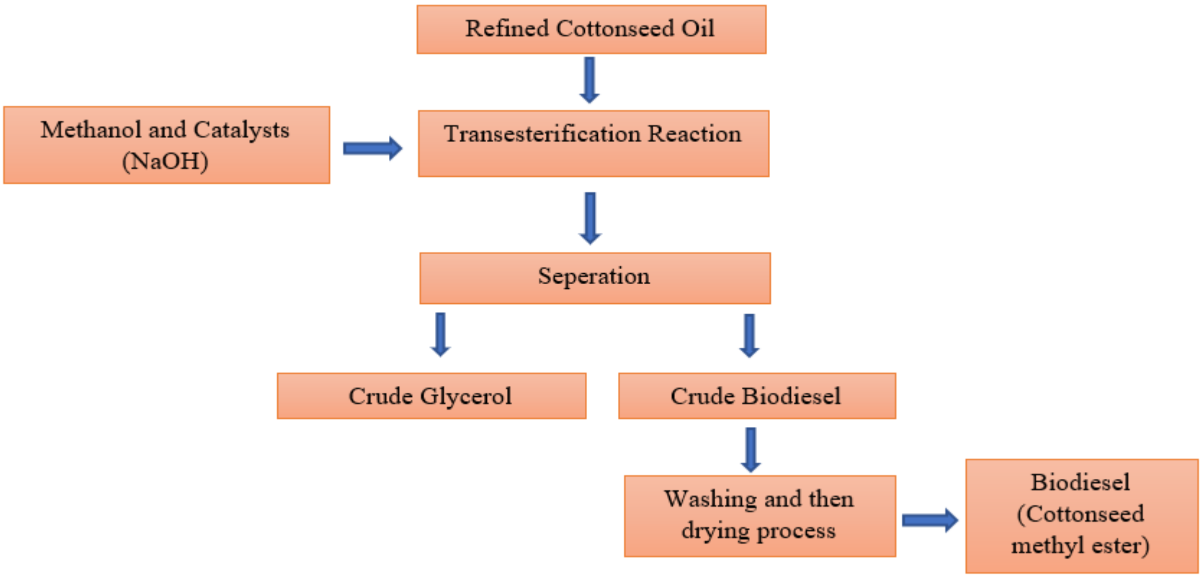

Figure 1. *Biodiesel production steps.*

Table 1. *Properties of cottonseed oil methyl ester, diesel, and methanol [10].*

Property	DF	BD20	BD20AL20	AL20	Method
Density (mm^2/s; 15 °C)	842	851	840.6	831.6	EN ISO 3675
Cetane number	54.92	53.304	43.32	44.936	-
Kinematic viscosity (mm^2/s; 40 °C)	2.4	3.2	2.6	1.9	EN ISO 3104
Lower heating value (MJ/kg)	43.2	41.7	37.1	38.3	UNE 51123
Flashpoint (°C)	92.5	104	87.7	76.2	EN ISO 2719
Carbon (wt. %)	86.74	83.584	73.736	76.892	-
Hydrogen (wt. %)	13.26	12.894	12.742	13.108	-
Oxygen (wt. %)	0	1.892	11.892	10	-

B. TEST OPERATING CONDITIONS

Engine performance and combustion tests were performed on a single-cylinder direct injection air cooled diesel engine. Before the experiment, the fuel pump and injector settings of the engine were made according to the original values (207 bar). The experiments were carried out at full throttle position in the range of 1750-3250 rpm and 500 rpm intervals when the engine oil temperature reached 40 ºC. DF, BD20, AL20, and BD20AL20 fuels were obtained by mixing cotton oil methyl ester and methanol in DF in different ratios. All experiments were repeated 3 times under the same conditions and the averages of the data were taken. A Kemsan brand electric dynamometer and Kistler torque measurement sensor were used for torque and power measurements, which can absorb 15 kW of power. Fuel consumption was determined by measuring the amount of fuel consumed per minute in a millimeter-scale burette. The technical characteristics of the test engine are given in Table 2 and the schematic view of the test setup is given in Figure 2.

Table 2. *Specifications of the diesel engine.*

Model	Lombardini 15 LD 350
Maximum power	7.5 HP/3600 rpm
Engine type	Naturally-aspirated, air-cooled, DI diesel engine
Displacement	349 cm^3
Maximum torque	16.6 N.m/2400 rpm
Nozzle opening pressure	207 bar
Bore × stroke	82 mm × 66 mm
Injection pump type	QLC type
Injection nozzle	0.22 × 4 holes × 160°
Compression ratio	20.3/1
Fuel delivery advance (°CA)	20 BTDC
Cylinder number	1
Intake valve open/close (°CA)	10 BTDC/42 ABDC

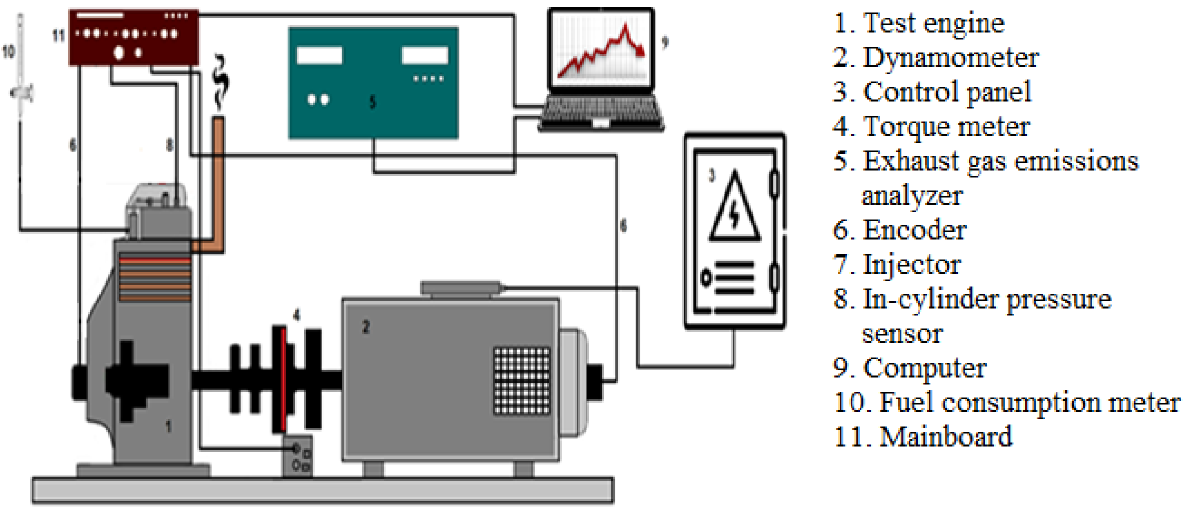

Figure 2. *Schematic view of the experimental setup [23].*

In-CP measurement and combustion analysis were carried out with Febris software. Optrand Auto PSI-TC model is connected to the in-CP sensor and the Kübler sendix brand encoder Febris software, which is connected with the coupling to the crank axis. Thus, in-CP data was recorded for each 1° crank angle. Depending on the crank angle, the rate of HRR was taken under the same conditions for each test fuel. All calculations were made by taking the average values of 1000 cycles of the engine. The HRR was calculated according to Equation 1 according to the first law of thermodynamics [24].

$$\frac{\partial Q_n}{\partial \emptyset} = \frac{k}{k-1} P \frac{\partial V}{\partial \emptyset} + \frac{1}{1-k} V \frac{\partial P}{\partial \emptyset} \tag{1}$$

Here, k is a polytropic constant, and 1.37 was taken. n is the polytropic index. ∂V indicates volume change and ∂P CP change. Ø is the crank angle. In the calculations, it is assumed that the mass entering the cylinder does not change and the ideal gas is inside the cylinder.

Additionally, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were used to discuss engine performance relative to test fuels. These metrics were calculated by Equations (1), (2), and (3) [24].

$$Pe = \frac{2\pi.\omega.T}{1000} \tag{2}$$

In Equation (2), T, ω, and P_e are the torque value (Nm), angular velocity (1/s), and Power Brake (kW), respectively [24].

$$BSFC = \frac{\dot{m}_f.10^3}{P_e} \tag{3}$$

In Equation (3), m_f is the fuel mass rate (kg/h) and BSFC is brake specific fuel consumption (g/kWh), respectively [24].

$$BTE = \frac{P_e.3600}{m_f.LHV}.100 \tag{4}$$

In Equation (4), BTE and LHV are brake thermal efficiency (%) and lower heating value of the test fuels (kJ/kg), respectively [24].

The total uncertainty value of the experimental study was calculated by the following equations. In the equation, W_R is the total uncertainty of the study (%), R and w are the uncertainty function and the dimensional factor, respectively. In the same equation, W_n expresses the uncertainties in the independent variables [25].

$$W_R = \left[\left(\frac{\partial R}{\partial x_1} w_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} w_2 \right)^2 + \ldots\ldots\ldots\ldots + \left(\frac{\partial R}{\partial x_n} w_n \right)^2 \right]^{1/2} \tag{5}$$

The specifications of all measurement instruments are given in Table 3.

Table 3. *Properties of the measurement equipment.*

No	Measuring Instrument	Range	Units	Accuracy
1	Thermocouple (K-Type)	0-1200	°C	± 0.1°C
2	Pressure (Optrand Auto PSI-TC)	0-20.68	MPa	± 1 %
3	Crank angle encoder (kübler sendix)	0-360	°	± 1 %
4	Fuel flow burette	0-100	ml	± 1 %
5	Torque measuring system (Kistler Rotor type 4550A)	0 ±100 to 0 ±5000	Nm	0.05 %

III. RESULT AND DISCUSSION

In this study, the effect of diesel-biodiesel-methanol blends on combustion and engine performance in a diesel engine was investigated experimentally. DF, BD20, AL20, and BD20AL20 were used as test fuels. The experiments were carried out between 1750-3250 rpm engine speeds and 207 bar injection pressure. The overall uncertainty value of this study is 1.73%. As a result, the following results can be achieved in this study.

A. PERFORMANCE CHARACTERISTIC

Burning neat diesel fuel instead of using other additives such as biodiesel and alcohol gives better results in terms of fuel consumption and thermal efficiency. However, improving the emission value of diesel fuel, which is frequently on the agenda due to its emissions, and biodiesel and alcohol are used as an alternative fuel to crude oil, which is expected to be exhausted in the near future. Biodiesel fuel can be used as a fuel equivalent to standard diesel fuel by improving the engine in terms of emission and performance values. In addition, biodiesel is used for recycling and energy conversion. When performing performance evaluation, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were discussed. In this context, Figure 3 indicates how to change BSFC depending on the test fuel and engine speed. As can be seen from the figure, BSFC increased as the alcohol and biodiesel content blended. The lowest BSFC was seen for DF test fuel, while the highest one was seen BD20AL20 test fuel at all engine speed. As well-known, BSFC addresses to the fuel amount that must be consumed to reach the same engine speed for the varying test fuel. With this viewpoint, the best performance was achieved for DF test fuel and the BSFC worsens with the decrease percentage of neat DF in the blend. The most important fuel properties directly affecting the BSFC is the heating value [26]. Based on Table 1, the heating value of test fuels can line up as follows: DF_{LHV}> $BD20_{LHV}$>$AL20_{LHV}$> $BD20AL20_{LHV}$. A test fuel with a lower heating value needs to inject more fuel to reach the same output as the comparison with the test fuel with a higher heating value. This is the reason why the highest BSFC is seen for BD20AL20 fuel in all cases. With the same logic, the lowest BSFC is seen for DF owing to the lowest heating value of DF in comparison with that of other all test fuels.

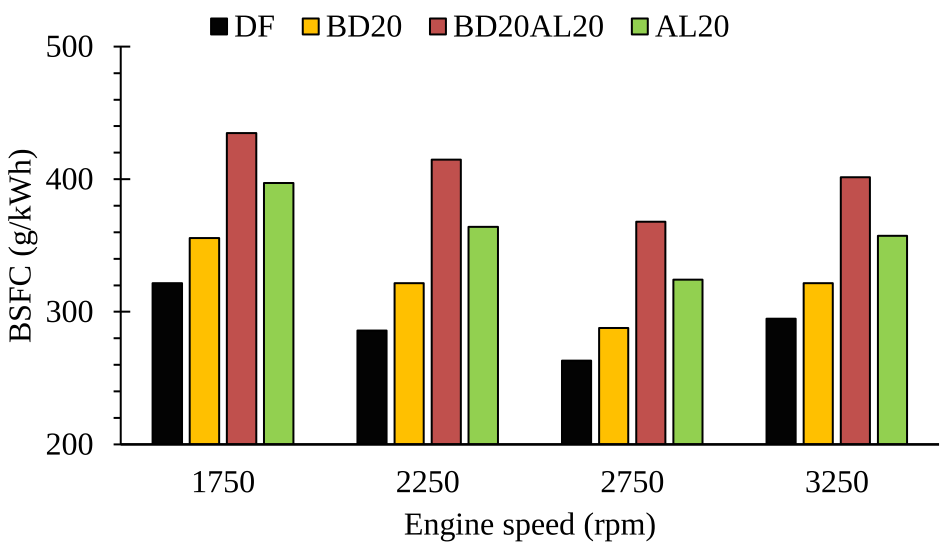

Figure 3. *Effect on BSFC of fuel blends in different engine speeds*

As seen in Figure 4, the reverse trends are noticed for BTE. One of the most significant factors affecting the BTE trend is the heating value of test fuels. BTE is an indicator of how to efficiently burn the fuel in the combustion chamber. The highest BTE is seen for DF because the heating value of DF is the highest one in comparison with that of other all fuels. With the same logic, the lowest BTE value at all engine speed is observed for BD20AL20 test fuel due to its heating value. As can be seen from Figure 4, BTE is increasing up to 2750 rpm and then it is slowly decreasing at 3250 rpm. The reason for that can be attributable to the injected fuel amount at 3250 rpm. Anymore, the fuel injected into the combustion chamber is relatively higher, and therefore the fuel does not have sufficient time to completely burn. That may be the reason why BTE is starting to decrease at 3250 rpm.

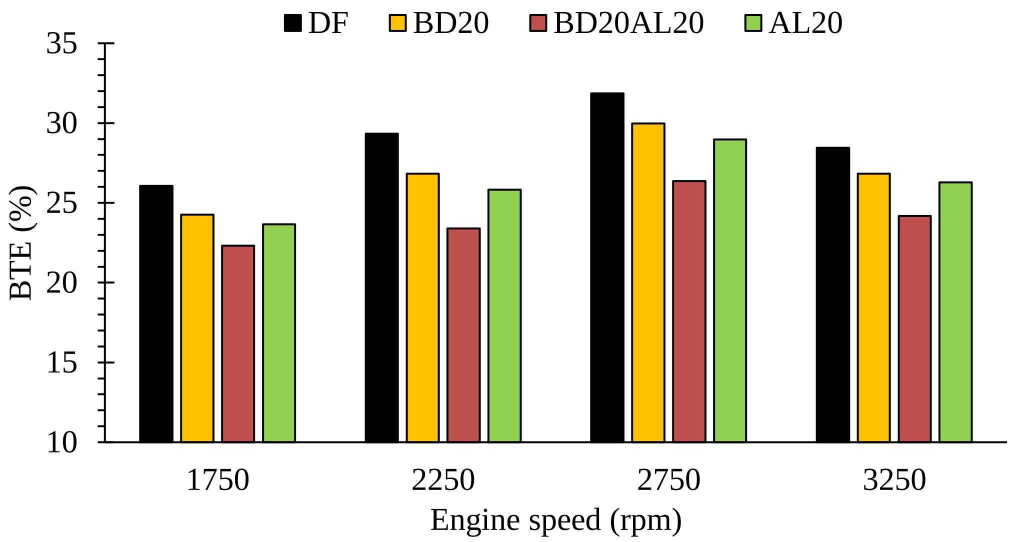

Figure 4. *Effect on BTE of fuel blends in different engine speeds*

DF has the highest BTE value with an average of 28.93% to the highest BTE value. The closest value to it is on average 6.8% lower with BD20 fuel. The main reason why BD20 fuel has values close to DF is the cetane number it has. Higher cetane number of DF ensures a shortened ignition delay for this fuel, and thus its combustion duration period will be longer than that of other test fuels. Besides, another reason of low BTE with DF can be attributable to higher energy content of DF as compared to that of biodiesel and alcohols. Similar results were also reported in [6, 7, 17, 25, 27].

B. COMBUSTION

Combustion properties such as HRR and CP are parameters that seriously affect the engine performance. The physical and chemical properties of test fuels significantly affect the performance and combustion properties of diesel engines. The effects of test fuels on CP and HRR are shown in Figure 5-8 according to different engine speeds. As can be seen from these graphs, CP_{max} values for each fuel type decreased due to the increase in engine speed, and the highest CP_{max} values were reached at 1750 rpm. The starting point of the combustion process approaches the top dead point due to the increase in engine speed. Besides, this situation reduces the duration of the uncontrolled combustion phase at high speeds, thereby increasing the controlled combustion time and lowering the CP_{max} values. Reducing the CP_{max} value due to engine speed and likewise reduced HRR_{max} values for each fuel type based on engine speed. Also, ID is another parameter that greatly affects the combustion process. The cetane number, oxygen content and atomization rate of the fuels used also affect this situation.

As seen in Table 1, the lowest cetane number is in BD20AL20 with 43.32. Then AL20 closely followed BD20AL20 test fuel with the cetane number of 44.94. On the other hand, the highest cetane number belongs to neat DF. As well-known, the test fuels with lower cetane numbers lately ignite. However, owing to late ignition, the fuel-injected starts accumulation in the combustion chamber. When it reaches the ignition temperature, a rapid ignition begins therein. This is why higher peak points are observed in CP_{max} and HRR_{max} with the test fuels with a lower cetane number. Additionally, as can be seen from Figures 5-8, the curves of these test fuels started to rise later with the rapid ignition of the fuel accumulated.

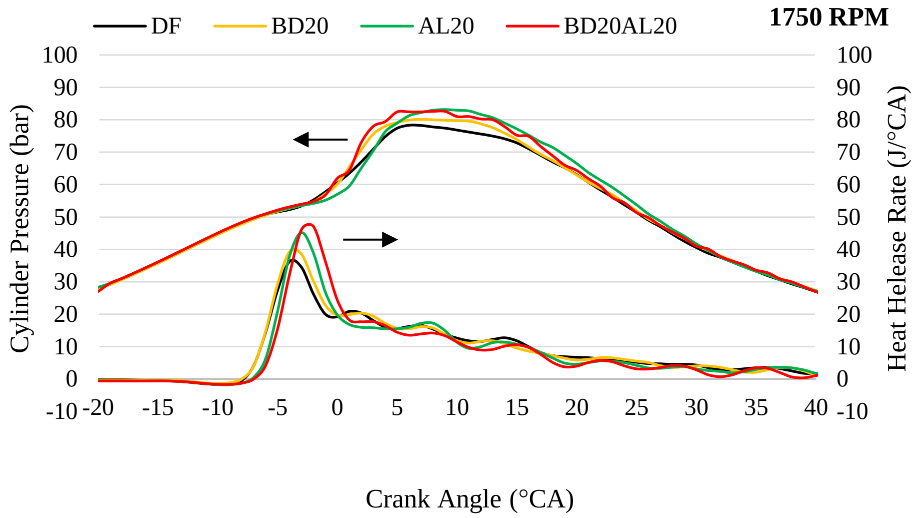

Figure 5. *Changes crank angle and heat release rate at 1750 rpm*

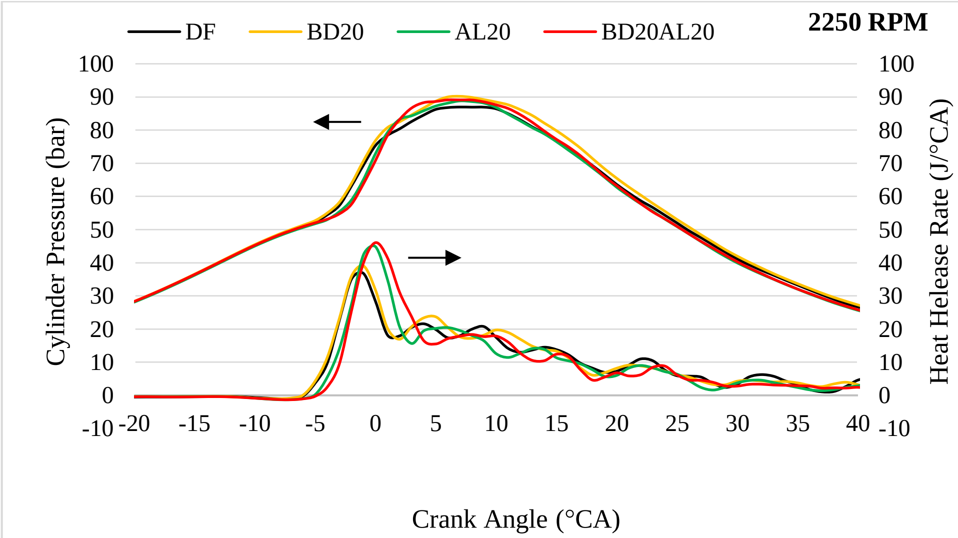

Figure 6. *Changes crank angle and heat release rate at 2250 rpm*

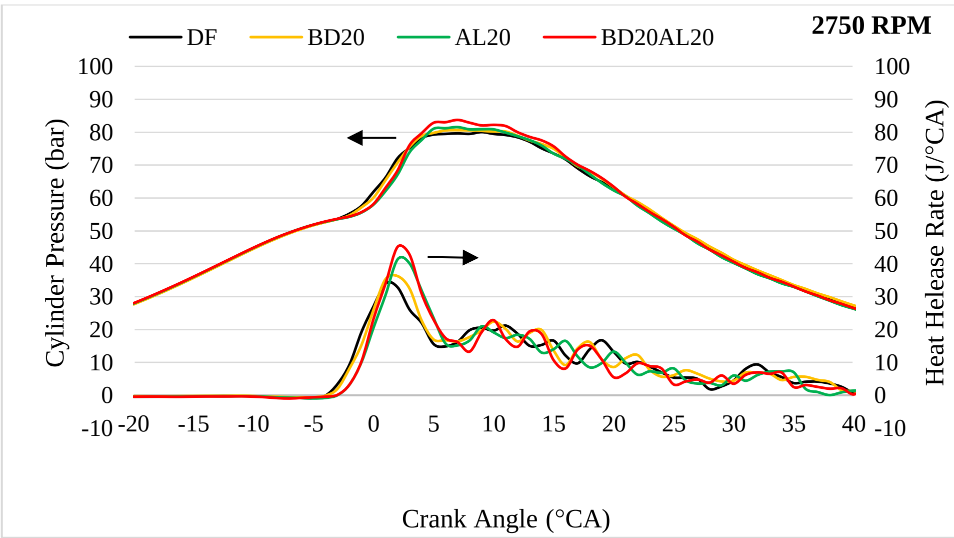

Figure 7. *Changes crank angle and heat release rate at 2750 rpm*

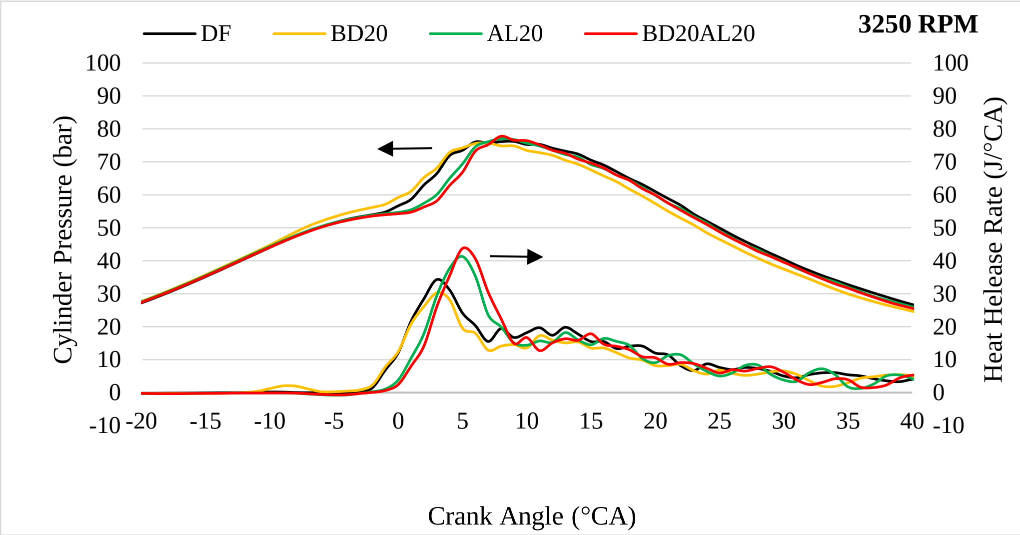

Figure 8. *Changes crank angle and heat release rate at 3250 rpm*

In Figure 6, although diesel fuel has a greater ignition delay, a higher CP value was encountered in BD20AL20 fuel. In the occurrence of this situation, the increase in engine speed, the change in the fuel amount, the change in the viscosity value with the temperature value, the change in the density with the temperature and the speed, the change of the atomized texture of the fuel and the standard error margin are effective.

Viscosity, which is one of the characteristics of diesel fuel, generally means the resistance of liquids against flowing. An atomized fuel condition is required for good combustion. The particulate fuel will react more easily with the air and will return as a positive effect on other diesel fuel characteristics. In diesel engines, spraying the fuel into the cylinders in an atomized manner will improve the combustion condition and consequently the engine performance values will increase. In addition, the greater the viscosity value, the more power the injection system will need to spray fuel. A good combustion situation directly affects the specific fuel consumption, thermal efficiency and other curves.

The cetane number is one of the most important diesel fuel characteristics, generally referred to as diesel fuel. It shows the tendency of diesel fuel to burning. As the cetane number increases, the fuel's tendency to ignite increases. The low cetane number will make the ignition of the fuel coming from the injectors at the desired time unstable during the ignition period, and therefore the fuel accumulation in the combustion chamber will cause a sudden and higher amount of fuel. In Figure 8, the first rising curve in the combustion graph is BD20 fuel. As can be seen in the graph, the ignition of diesel fuel is earlier and the first rising curve in the CP_{max} graph is BD20 fuel. Although its cetane number is low, it is seen to have a similar ignition tendency to diesel fuel. However, in blends using alcohol, this happens later. Therefore, it can be said that alcohol reduces the cetane number.

IV. CONCLUSION

The effects of diesel-cottonseed oil methyl ester-methanol blends on performance and combustion at different engine speeds in a single-cylinder direct injection diesel engine were investigated. As a result of this study, the following information was obtained:

- Adding cotton oil methyl ester and methanol to DF has changed the chemical and physical properties of DF.
- DF has the highest BTE and lowest BSFC values due to its heating value.

- BTE increased up to 2750 rpm at all test fuels. After this point, BTE started to decrease because of more fuel was injected into the combustion chamber at 3250 rpm. The fuels do not find sufficient time to completely burn therein. This case results in incomplete combustion and thereby BTE lost its increasing trend for all test fuels as the engine speed changed from 2750 to 3250 rpm.

- Peak points of binary and ternary test fuels in the CP and HRRs are higher than DF. The reason for that is that the addition of biodiesel and alcohol into DF results in lower cetane number. Test fuels lately ignite as the cetane number of them decreases. This case causes fuel to accumulate in the combustion chamber. This accumulated fuel ignites suddenly and reaches higher peak points for these fuels.

By setting the rates higher, the changes that occur can appear more clearly. In addition, the product obtained by making cost analysis together with the rates can be evaluated in terms of cost. In addition to these, by adding nanoparticles to diesel and biodiesel recently, good results are obtained in engine performance and combustion properties. When using hybrid nanoparticles in the use of nanoparticles, the changes in the performance values of the system can be examined in the future.

V. REFERENCES

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