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Research Article

Experimental Analysis of The Impacts of Biodiesel-Diesel Fuel Mixtures on Engine Vibration, Noise and Combustion

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ABSTRACT

The restricted reserves of fossil-based fuels and the regulations imposed on emission standards increase the importance of renewable fuels. Biodiesel is one of among peripherally friendly and renewable disjunctive fuels and contributes to the reduction of exhaust emissions. Biodiesel fuels have distinctive chemical frames and fuel features compared to conventional diesel fuels based on their substance and production method. Ignition delay, pressure increase rate, and combustion characteristics generate mechanical noises and vibrations in the engine. In compression-ignition engines, high noise and vibration eventuating from the explosive burning have negative effects on the environment and living beings. In this search, the impacts of various proportions of biodiesel fuel and conventional diesel fuel blends on the in-cylinder pressure, vibration, and noise of a three-cylinder water-cooled diesel engine were experimentally investigated. The peak max in-cylinder pressure values for all test fuels were obtained at 15 Nm. For all test fuels, the largest vibration value was obtained at 15 and 60 Nm and the smallest vibration value was obtained at 45 Nm. The engine noise level is reduced up to 45 Nm and increased at 60 Nm. The highest noise level was obtained with conventional diesel fuel (D) at all engine loads. The addition of biodiesel to the test fuels reduced the noise level at all loads. The average noise values of all test fuels are 90.58, 90.28, 90.35, and 90,09 dBA for 15, 30, 45, and 60 Nm loads, respectively.

Keywords: *Engine Vibration, Noise, Combustion*

Biyodizel-Dizel Yakıt Karışımlarının Motor Titreşimi, Gürültü ve Yanma Üzerindeki Etkilerinin Deneysel Analizi

ÖZ

Fosil bazlı yakıtların rezervlerinin kısıtlı olması ve emisyon standartlarına getirilen düzenlemeler yenilenebilir yakıtların önemini artırmaktadır. Biyodizel yakıtlar, çevre dostu ve yenilenebilir ayrık yakıtlardan biridir ve egzoz emisyonlarının azaltılmasına katkıda bulunur. Biyodizel yakıtlar, içeriklerine ve üretim yöntemlerine bağlı olarak geleneksel dizel yakıtlara kıyasla farklı kimyasal yapı ve yakıt özelliklerine sahiptir. Yakıtın tutuşma gecikmesi süresi, basınç artış hızı ve yanma özellikleri motorda mekanik sesler ve titreşimler oluşturur. Dizel motorlarda patlamalı yanma sonucu oluşan yüksek gürültü ve titreşim, çevre ve canlılar üzerinde olumsuz etkilere sahiptir. Bu çalışmada, farklı oranlarda biyodizel yakıt ve geleneksel dizel yakıt karışımlarının üç silindirli, su soğutmalı bir dizel motorun yanma basıncı, titreşimi ve gürültüsü üzerindeki etkileri deneysel olarak incelenmiştir. Tüm test yakıtları için maksimum silindir içi basınç değerleri 15 Nm'de elde edilmiştir. Tüm test yakıtları için en büyük titreşim değeri 15 ve 60 Nm'de, en küçük titreşim değeri ise 45 Nm'de elde edilmiştir. Motor gürültü seviyesi 45 Nm'ye kadar azalmış ve 60 Nm'de artmıştır.

Anahtar Kelimeler: *Motor Titreşimi, Gürültü, Yanma*

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I. INTRODUCTION

The fact that fossil-based fuels have limited reserves and emit harmful emissions. For these reasons, it is important to develop renewable and eco-friendly fuels that can replace fossil-based fuels. Renewable energy sources being sustainable will reduce the need for fossil-based fuels. Biodiesel fuels are renewable alternative fuels derived from animal and vegetable fats and oils, and waste oils by transesterification method. The oxygen content of biodiesel fuels reduces the exhaust emissions of diesel engines. Biodiesel is a fuel composed of a mixture of long-chain carboxylic acid ester alkyls and can be mixed with conventional diesel fuel in any blend ratio [1-4]. Biodiesel fuels can be used in diesel engines without requiring any modification to the engine since their features are similar to those of petroleum-derived diesel [5-8].

Engine vibration is a factor affecting vehicle vibration and is important for fault detection and driving comfort. Vibration amplitude has negative effects on engine parts and noise has negative effects on life. The main causes of engine vibrations and noise are combustion, knocking, and movement of engine parts. Diesel engine noise consists of exhaust, intake, and combustion noises and mechanical noise from engine components. Mechanical noise due to factors such as piston clearances, deformation, and friction is affected by the end combustion pressure. In diesel engines, the conventional combustion process, which depends on engine load, speed, and fuel features, is the most significant source of noise [9]. Burning noisiness is extremely based on fuel combustion and is a consequence of the harshness and unevenness of fuel self-ignition. Since the end-combustion pressure forces and combustion speed depend mainly on the injection strategy, fuel specifications like cetane number, calorific value, kinematic viscosity, and density play an important role in reducing these forces [10]. The pressure and mechanical forces generated during combustion cause vibration on the engine block. The amplitude of the maximum vibration gives information about the combustion intensity. Early ignition of the fuel and rich mixture increases the vibration amplitude. Late ignition, injector failure, and compression leaks reduce the vibration amplitude [11]. Large vibration amplitude could also damage the electronic and mechanical components of vehicles. Large vibration amplitude will reduce engine life due to the knocking phenomenon and detonation during combustion, which may also degrade the thermal efficiency [12]. Knocking in diesel engines is a phenomenon that also depends on fuel features. The loudness level of ICE depends on the mechanical forces acting on the moving parts, which vary depending on the biggest in-cylinder pressure and the heat release rate. The in-cylinder pressure acting on the combustion chamber and piston surface creates vibration in the engine block. As a result of vibration, noise is emitted into the environment. The combustion process, which is subject to fuel type, engine specifications, and engine operating specifications, is the most important source of vibration and noise [13]. In spite of there are various searches in the books and articles examining the influence of biodiesel-mixed fuels on engine performance and emissions, it has been observed that studies examining the impact of biodiesel-mixed fuels on engine noise and vibration are limited. In the study by Sarıdemir and Ağbulut, the impact of varied ratios of conventional diesel-cotton oil methyl ester on engine vibration and noise under several loads at a steady engine rotation of 1500 rpm was investigated. The least mean vibration value was achieved with B20 test fuel. It was reported that the noise values of the experiment fuels were near to one another at the same engine load [13]. In a study by Patel et al., vibration and noise values of a single-cylinder engine were studied in relation to load. Karanja biodiesel (KB100), KB20, and pure diesel fuel were used as test fuels. The highest noise and vibration values in the vertical direction were obtained with KB20 fuel [14]. In the study by Uludamar and Aydın, the influence of diesel fuel and diesel fuel sunflower, canola, and corn oil biodiesel fuel mixtures on engine noise and vibration depending on engine speed was investigated. The results showed that the noise and vibration of the engine decreased with increasing biodiesel ratio until pure biodiesel usage [15]. In the study by Çelebi et al., the acoustic and vibration effects of biodiesel and its blends were investigated. The experimental engine was fed with conventional diesel, sunflower, and canola biodiesel blends at 20% and 40% by volume. In addition, natural gas was supplied through the intake manifold at 5 L/min, 10 L/min, and 15 L/min. The results showed that sunflower and canola biodiesel reduced the sound pressure level and vibration of the test engine compared to conventional diesel fuel [16]. In the study by Çalık, the effects of conventional diesel, pure waste oil biodiesel, and hydrogen addition to these fuels on engine vibration were investigated. It was reported that pure biodiesel and hydrogen addition to pure biodiesel and conventional diesel reduced engine vibration [17]. Alisaraei et al. examined the impacts of neat diesel fuel, waste biodiesel fuel (B100), and biodiesel-diesel fuel blends (B20, B40, B60, B80) on combustion and vibration. It is stated that maximum vibration values are obtained with B20 and B40 and minimum vibration values are obtained with D100 and B80 [18]. Redel-Macías et al. enquired about the effect of palm oil biodiesel and olive pomace oil biodiesel on engine noise. It was reported that POME and OPME fuels reduced noise and the lowest noise level was obtained with PME50 [19]. Manieniyan and Sivaprakasam enquired about the impact of conventional diesel and Mahua biodiesel fuels on engine vibration at a stable speed of 1500 rpm and different loads. It was reported that biodiesel fuel increased the vibration level in the cylinder head and reduced the vibration of the lower part of the engine [12].

Canola oil has a wide production potential in our country. In the books and articles, there are studies investigating the effects of biodiesel fuel blends obtained from various vegetable and waste oils on engine vibration and noise. Vibration and noise are important factors affecting driving comfort. In the literature, it has been observed that the studies investigating the impacts of canola oil biodiesel on engine vibration and noise are limited. Therefore, in this study, the impacts of different ratios of canola oil biodiesel and conventional diesel fuel blend on combustion, vibration, and noise were experimentally investigated.

II. MATERIAL AND METHOD

Biodiesel fuel was manufactured from refined canola oil by transesterification with the production procedure shown schematically in Figure 1. The produced canola methyl ester was blended with conventional diesel fuel at 10, 30, and 50% by volume just before the experiments to obtain B10, B30, and B50 test fuels.

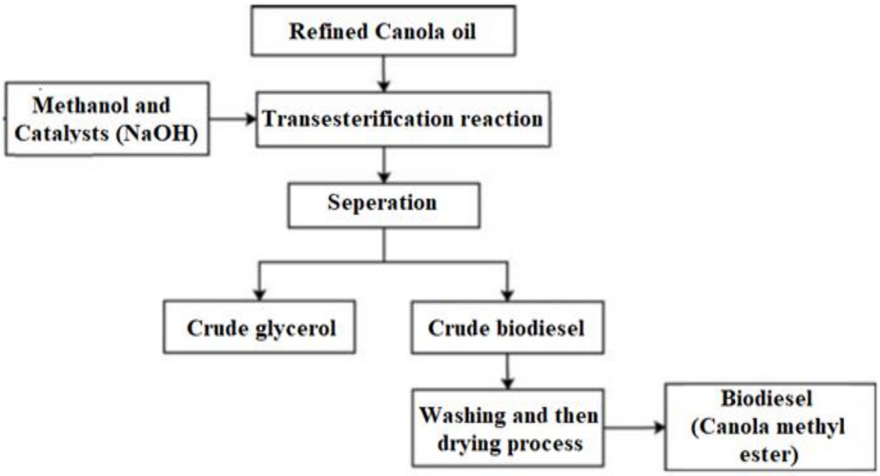

Figure 1. *Canola oil methyl ester production scheme.*

Some of the primary features of the test fuels are given in Table 1.

Table 1. *Some main characteristics of the test fuels.*

Property	D	C10	C30	C50
Density (kg/m^3; 25 °C)	844	848	852	861
Lower heating value (MJ/kg)	44.86	44.30	43.14	42.31
Viscosity, (cSt @40 °C)	2.68	3.07	3,38	3.61
Cetane number	54	53	51	49

The tests were handled with a three-cylinder, water-cooled diesel engine whose specifications are given in Table 2. All experiments were started under the same conditions when the engine oil temperature approached 50 ºC.

Table 2. *Tech. features of the test engine.*

Model	**Lombardini LDW 1003**
Engine type	Four-stroke, direct injection (DI)
Number of cylinders	3
Total cylinder volume	1028 cm^3
Bore–stroke	75 mm–77.6 mm
Compression ratio	22.8:1
Maximum engine power	19.5 kW (26.5 Hp)
Maximum engine speed	3600 rpm
Maximum engine torque	67 Nm/@2000 rpm
Cooling type	Water-cooled
Valve timing (IVO/IVC)	16 BTDC/36 ABDC °CA
Valve timing (EVO/EVC)	36 BBDC/16 ATDC °CA

During the experiments, engine oil and exhaust degree of heat were measured with K-type NiCr-Ni coated thermocouples. All experiments were performed at a stable engine speed of 2000 rpm under loads ranging from 15-60 Nm with 15 Nm intervals. The engine was uploaded by a Kemsan brand electric dynamometer with a maximum power absorption capacity of 22 kW. The speed and torque values of the engine under all loads were measured with a Kistler Rotor type 4550A model magnetic torque meter. In-cylinder pressure values varying with crank angle were measured with an Oprant AutoPSCI-TC model fiber optic pressure sensor fastened up on the glow plug seat of the engine. The engine crank angle was measured with a Kübler-Sendix model encoder. Figure 2 shows a diagrammatic view of the probatory setup.

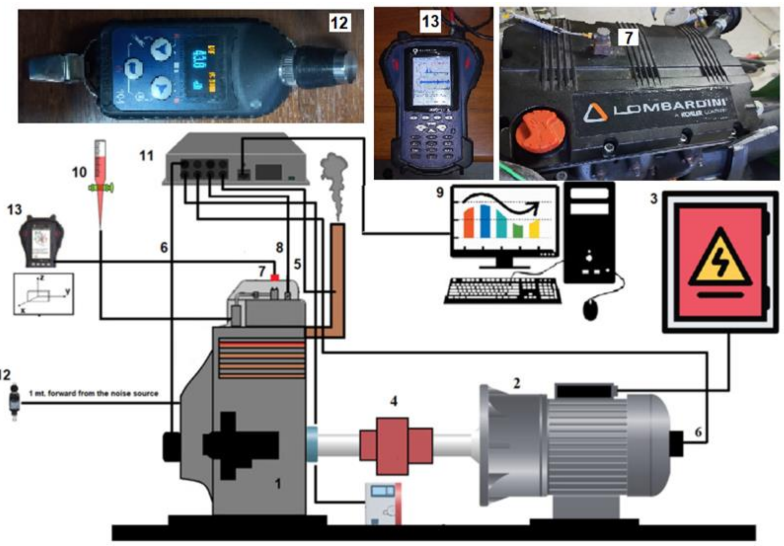

Figure 2*. The schematically view of experimental-setup.1. Test engine 2. Dynamometer 3. Control panel 4. Torque metre 5. Exhaust temperature point 6. Encoder 7. Accelerometer 8. Cylinder pressure sensor 9. Computer 10. Fuel con-sumption level 11. Mainboard 12. Noise measurement device 13. Vibration measurement device*

The data from the pressure sensor and encoder were transferred to the Febris combustion analysis software. With this software, in-cylinder pressure data were obtained for each experiment as a function of crank angle by averaging 1000 cycles of the engine. According to the in-cylinder pressure data obtained, the heat release rate was estimated with the consecution equation.

$$HRR = \frac{\gamma}{\gamma-1} P \frac{dV}{d\theta} + \frac{1}{\gamma-1} V \frac{dP}{d\theta} \; (J/°CA) \tag{1}$$

where HRR, γ, P, and V are heat release rate (J/◦CA), rate of specific heat (-), in-cylinder pressure (bar), and volume of cylinders (cm^3), respectively.

The totality uncertainty percentage of the consequences is found with the consequent equation.

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

In Eq. (2), W_R shows the total uncertainty (%) of the results, w and R are dimensional shape factors and the uncertainty function, respectively. In addition, w_n are the uncertainties in the independent variables. Table 3 presents a detail for the equipment. For noise measurement, Svantek 104 model noise meter (dosimeter) was used. For noise measurement, the device was placed 1 m away from the engine block in conformality with ISO 362-1:2007. Vibration measurement data were taken with a four-channel VIBROTEST 80 model FFT analysis data acquisition device with a 4527 model uniaxial piezoelectric accelerometer. The instrument has a Brüel&Kjaer program and hardware system. The data were filtered and analyzed at 6400 precision with the Hanning filtering method. Vibration inputs up to 5 kHz were taken in the tests. The sum amplitude mean of the vibration input was specified by the root mean square (RMS) method. The unit of vibration amplitude is (m/s^2). Time domain vibration data were recorded for 1.28 seconds at the specified sampling frequency. For every test, a sum of 16384 data was acquired from the accelerometer.

Table 3. *Measurement ranges, units, and accuracy of the experimental apparatus*

Measuring Instrument	Range	Accuracy
Pressure (Optrand Auto PSI-TC)	0-3000 psi	±1 %
Encoder (kübler sendix)	0-360°	0.1° CA
Torque Measuring Unit (Kistler Rotortype 4550A)	0 ± 100 to 0 ± 5000	0.01 %
Svantek SV 104	55 dBA RMS ÷ 140.1 dBA Pik	0.7 %

The vibration amplitude values obtained with all experimental fuels at different engine loads were analyzed comparatively. For this purpose, the root mean square (RMS) values of the vibration amplitude values measured with the accelerometer were calculated. The measured time domain amplitude values were calculated with the equation given in Equation 3 [15, 18].

$$a_{RMS} = \sqrt{\frac{1}{n} \sum_k^n a_k^2} \tag{3}$$

Here;

a_{RMS} : Root mean square root of acceleration values (m/s^2),

a_k: The k_{th} value of the time domain data (taken numerically from the accelerometer in the time domain),

n= Number of time domain acceleration inputs (n = 16384 for 1.28 s duration)

Vibration data were taken in one direction (vertical) for all test fuels.

III. RESULTS AND DISCUSSION

In this study, canola methyl ester was produced from the oil obtained from the canola plant, which grows abundantly in our country. The produced canola methyl ester was mixed with conventional diesel fuel at different ratios by volume to obtain C10, C30, and C50 fuel blends. The test fuels were tested under the same conditions at a stable engine speed of 2000 and variable loads of 15, 30, 45, and 60 Nm. The results addressed the variation of the test fuels on combustion, engine vibration, and noise behavior. The experiment was carried out with an overall uncertainty of 2.4% and the results of the experiment are described in the subsections of this chapter in relation to cause and effect.

A. COMBUSTION CHARACTERISTICS

The experimental engine, whose technical specifications are given in Table 1, has an abnormal combustion chamber. Since the pressure sensor in the test engine is jointed in the pre-combustion chamber through the glow plug housing, the pressure values acting on the pre-combustion chamber can be measured. Figure 3-6 shows the in-cylinder pressure and heat release rate values of the test fuels for all engine loads (15, 30, 45, 60 Nm) at a stable engine revolution of 2000 rpm, varying with crank angle. In pre-combustion chamber diesel engines, the fuel is sprayed into the pre-combustion chamber by a one-hole nozzle and the initial combustion starts in the pre-combustion chamber where turbulence is very high and continues with its spread to the main combustion chamber. Therefore, as seen in the pressure graphs, the first stage pressure increase occurred due to the start of pilot combustion in the abnormal combustion chamber. As shown in Figure 3-6, as combustion starts in the pre-combustion chamber at all engine loads, the in-cylinder pressure values start to increase. As the flame front spreads into the main combustion chamber, the second stage pressure increase occurs. In-cylinder pressure and heat release rate values are experimental data that provide information about engine noise and vibration values. The peak maximum in-cylinder pressure values for all test fuels were obtained at 15 Nm. As seen in Figure 3, the maximum in-cylinder pressure value at 15 Nm engine load rose subject to the biodiesel ratio in the test fuels increased. The maximum in-cylinder pressure values of the test fuels are 57.98, 59.37, 59.73, and 60.79 bar for D, C10, C30, and C50 fuels, respectively. As seen in Table 1, biodiesel-containing test fuels have smaller lower heating values and cetane numbers, and larger viscosity and density than conventional D fuel. The lower cetane number of biodiesel-containing fuels boosts the ignition delay time. This causes more fuel to accumulate in the combustion chamber along the ignition delay time. With the sudden combustion of more fuel accumulated along the ignition delay time, the test fuels increased the maximum in-cylinder pressure value and HRRmax values subject to the biodiesel content at 15 Nm load. In addition, the high density of biodiesel-containing fuels causes low atomization, which contributes to a longer ignition delay time. The high O_2 content of biodiesel-containing fuels also increased combustion efficiency, max. combustion pressure and HRRmax.

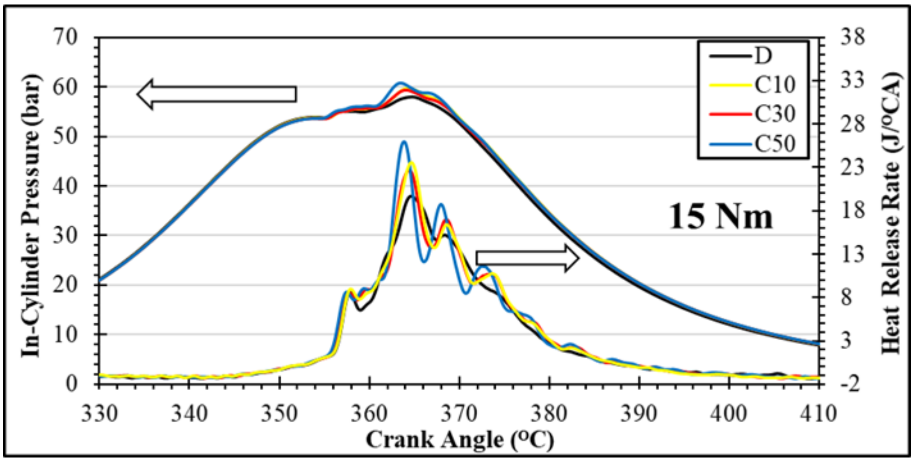

Figure 3. *Combustion pressure and HRR graphs of test fuels at 15 Nm load.*

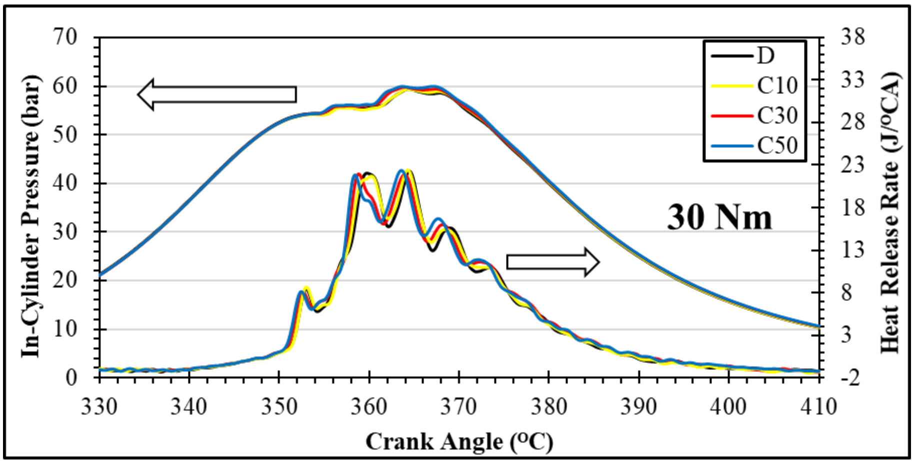

Figure 4. *Combustion pressure and HRR graphs of test fuels at 30 Nm load.*

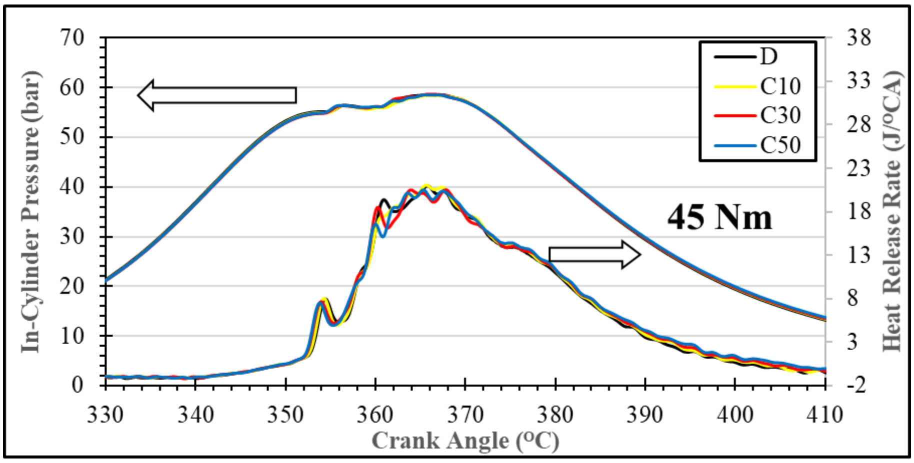

Figure 5. *Combustion pressure and HRR graphs of test fuels at 45 Nm load.*

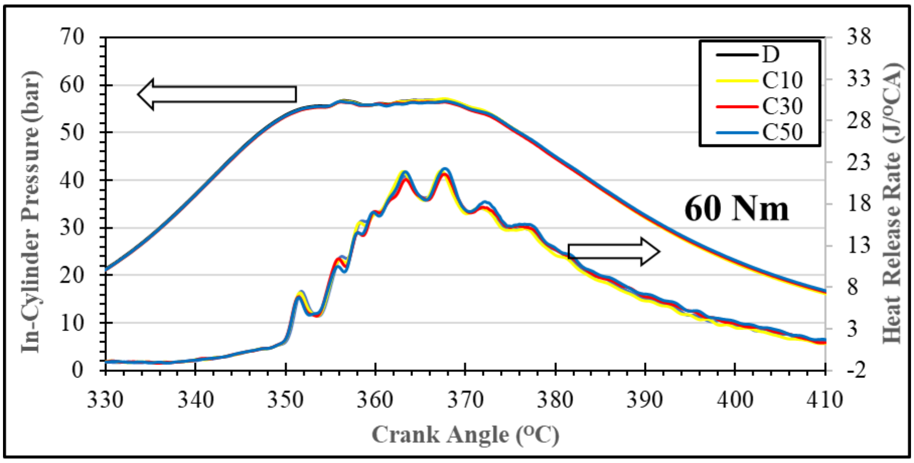

Figure 6. *Combustion pressure and HRR graphs of test fuels at 60 Nm load.*

In the literature, it is stated that the maximum combustion pressure values of single-cylinder and direct-injection engines increase with engine load. However, since the test engine used in this study has an abnormal combustion chamber, the maximum combustion pressure values for all test fuels decreased with engine load. This was due to increasing combustion temperatures with increasing engine load shortened the ignition delay time for all test fuels. At higher engine loads, there was less fuel deposition in the combustion chamber during the shorter ignition delay time. Therefore, while the maximum combustion pressure value decreased for all test fuels due to the increase in engine load, the combustion duration increased due to the increase in the amount of fuel injected from the injectors. Additionally, due to the increase in combustion duration, the piston moves away from the top dead center and combustion takes place in a larger volume depending on the increase in engine load. As seen in Figure 4-6, although more fuel is sprayed from the injector depending on the engine load, the increased combustion duration due to increasing load decreased the maximum in-cylinder pressure value. For these reasons, the maximum combustion pressure and heat release rate values for all test fuels were highest at 15 Nm and these values decreased with engine load. Biodiesel-containing fuels, which have a lower calorific value than conventional D, were injected into the combustion chamber in larger quantities in order to obtain the same torque value. For this reason, close pressure and heat release values were obtained with all test fuels depending on the increase in engine load.

B. VIBRATION AND NOISE CHARACTERISTICS

The pressure generated by combustion primarily generates pushing on the piston in the vertical direction. Therefore, only vibration data in the vertical direction were analyzed. The pressure wave generated by combustion impresses the combustion chamber surfaces, causing vibrations in the engine block.

Figure 7 shows the time domain vibration amplitude measured on the vertical axis as a function of time (1 second) with conventional D fuel at 60 Nm load. The time domain vibration amplitude shows the vibration amplitude obtained by injecting fuel from each injector for 1 second. The rotation speed of the engine per minute (2000 rpm) divided by 60 gives the revolutions per minute of the crankshaft circum its axis in 1 second (33.33). In four-stroke engines, the injector sprays fuel 1 time in 2 rotations of the crankshaft around its axis. Therefore, 1 injector sprays fuel 16.67 times in 1 second. Since the test engine has 3 cylinders, as a consequence of the combustion caused by every injector spraying fuel in 1 second, 16.67x3=50 vibration amplitude zones are formed as shown below. There are differences in the maximum amplitude values due to the mounting of the accelerometer on cylinder 1 and combustion irregularities.

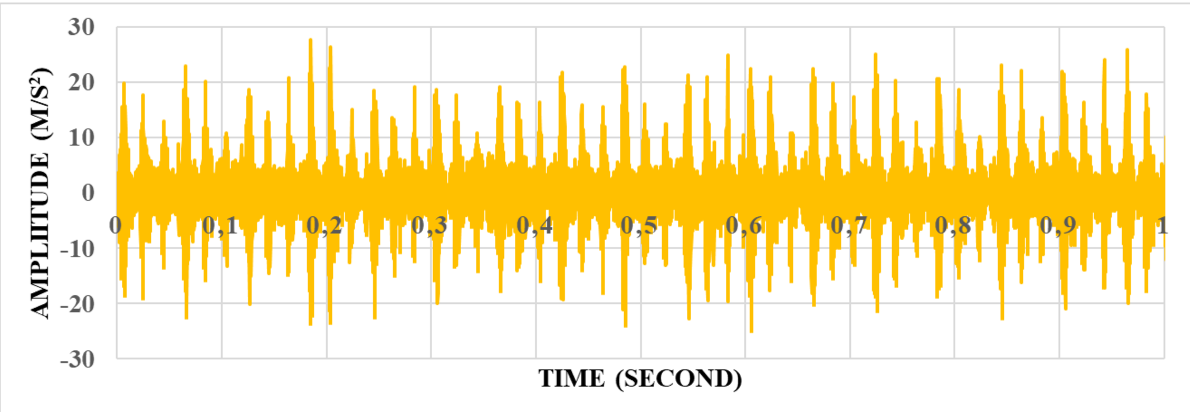

Figure 7. *Time domain vibration amplitude graph for D fuel at 60Nm (1 second duration)*

Figures 8-11 show the frequency spectrum of vibrations obtained by converting the time domain data to frequency domain data by Fast Fourier Transform (FFT) analysis for all loads. As seen in Figures 8-11, two peak amplitude values were obtained at all engine loads. Dominant frequency was observed about at half of the experimental speed. This is mainly due to the combustion of fuel were occurred at this frequency. These peak values were obtained at frequencies close to each other at 15, 30, and 60 Nm. At 45 Nm, the peak values are obtained at different frequencies. In addition, the first peak value is the smallest at 45 Nm. This can be attributed to the fact that the smallest HRRmax value is obtained at 45 Nm as seen in Figure 5. In addition, the largest peak values were obtained at 15, and 60 Nm, and the smallest peak values were obtained at 45 Nm. This can be attributed to the smallest HRRmax value at 45 Nm and the lower rate of pressure increase during combustion.

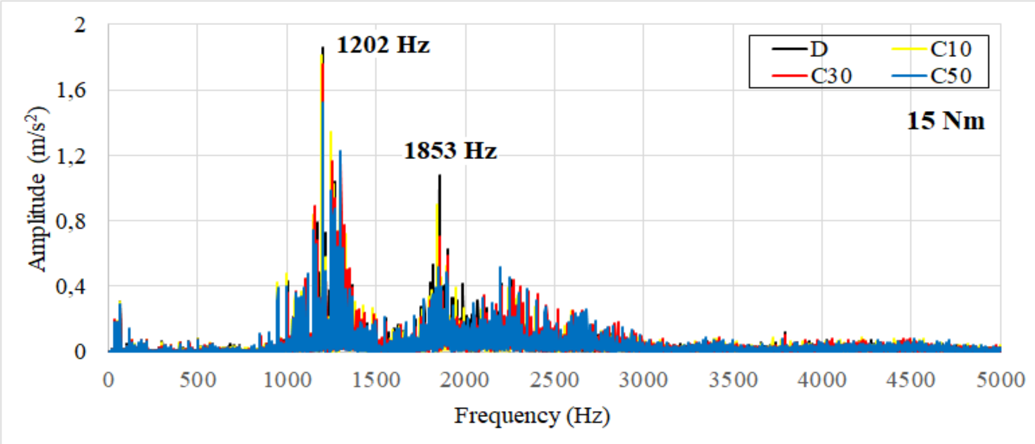

__Figure 8.__ The frequency spectrum of vibrations of test fuels at 15 Nm.

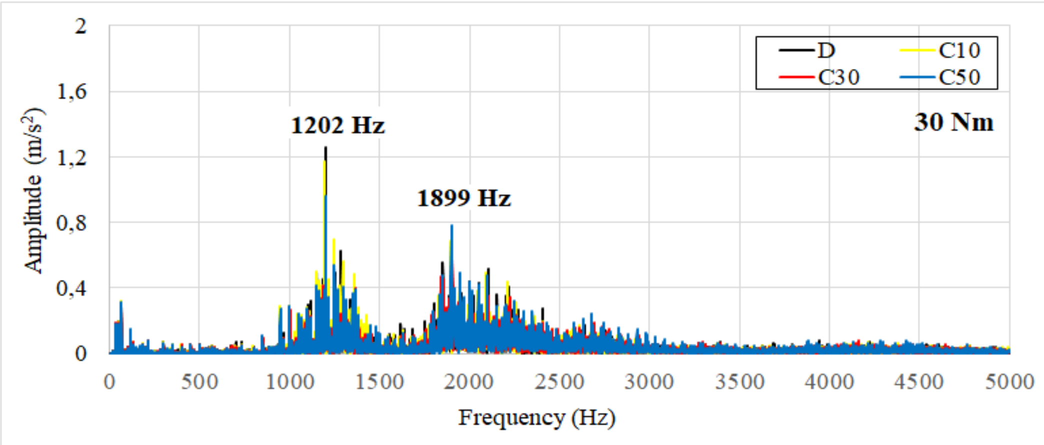

__Figure 9.__ The frequency spectrum of vibrations of test fuels at 30 Nm.

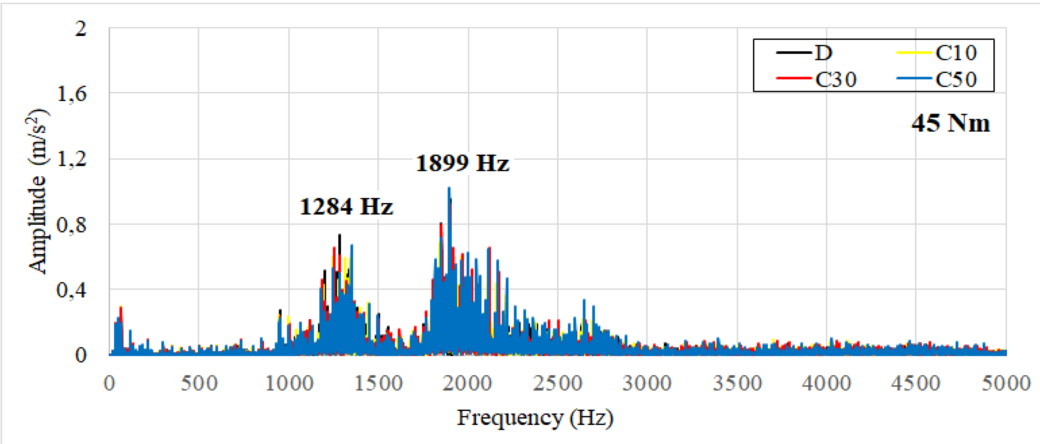

__Figure 10.__ The frequency spectrum of vibrations of test fuels at 45 Nm.

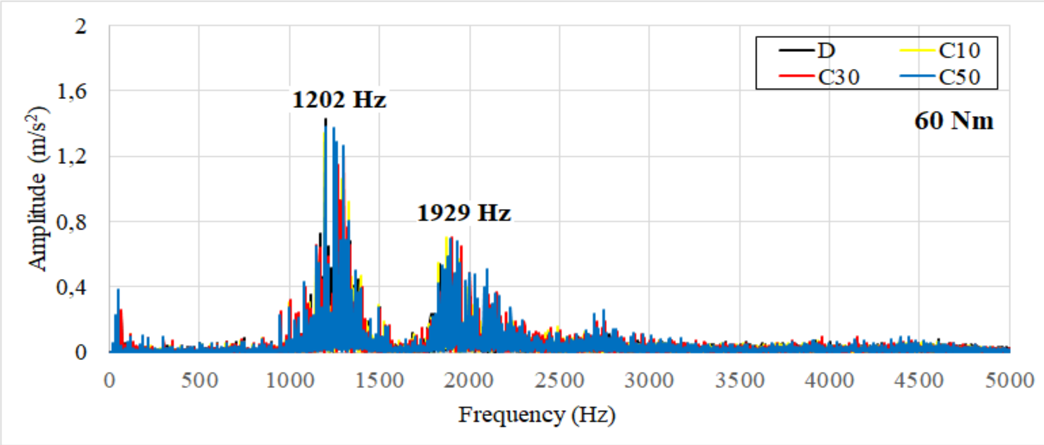

Figure 11. *The frequency spectrum of vibrations of test fuels at 60 Nm.*

The noise and vibration degree in internal combustion engines depends on the maximum in-cylinder pressure and the mechanical forces that vary with the rate of heat release and pressure rise. The increase in in-cylinder pressure primarily impresses the combustion chamber wall and gives rise to vibrations in the engine block. The consequent vibration creates noise. The in-cylinder combustion process is one of the most important noise sources. The maximum cylinder pressure rise rate, which is also influenced by fuel characteristics, affects the combustion speed. Figure 12 shows the Root Mean Square values (a_{RMS}) of the acceleration values of the test fuels as a function of engine load. The average a_{RMS} values of all test fuels are 4.9, 4.5, 4.17, and 4.83 m/s^2 for 15, 30, 45, and 60 Nm loads, respectively.

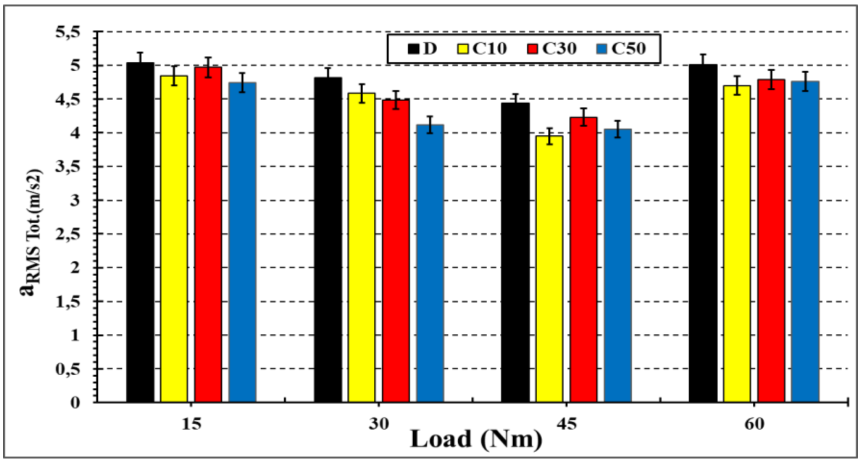

Figure 12. *Root mean square values (a_{RMS}) of test fuels as a function of load.*

At 15 Nm, due to the lower combustion chamber temperature, the ignition delay time of all test fuels was longer than at other loads, which improved the combustion speed and the rate of pressure increase. At 60 Nm, more fuel injected through the injectors also increased the rate of pressure increase and the duration of combustion. At 45 Nm the HRRmax values of all test fuels are the smallest. For these reasons, the biggest vibration value for all test fuels was obtained at 15 and 60 Nm and the smallest vibration value was obtained at 45 Nm, as shown in Figure 12. As seen in Figure 12, the largest a_{RMS} values were obtained with conventional D and the smallest a_{RMS} values were obtained with C50 at all loads. The addition of biodiesel to conventional D fuel reduced engine vibration and the a_{RMS} values at all loads were 4.83, 4.52, 4.62, and 4.42 m/s^2 for D, C10, C30, and C50 fuels respectively. This can be attributed to the reduced rate of increase in gas pressure in the cylinder due to the biodiesel content in the test fuel and less pressure fluctuations during the combustion phase. The cetane number, flash point, viscosity, lubricating features, thermal features, physical features, and chemical and molecular structure of the fuel affect vibration variations [20]. The level of combustion noise depends on the rate of increased combustion pressure, which in turn depends on parameters such as injection timing and ignition delay. The high viscosity and low cetane number of biodiesel-containing fuel blends reduce engine noise emissions. The average noise values of the test fuel at 2000 rpm as a function of engine load are given in Figure 13. The highest noise level was obtained with conventional diesel fuel (D) at all engine loads. The addition of biodiesel to the test fuels reduced the noise level at all loads. The reduction in noise level with biodiesel-containing test fuels is associated with reduced engine vibration. Therefore, in parallel with the decreasing trend in engine block vibration, the noise level also decreased with biodiesel-containing fuels. The average noise values of all test fuels are 90.58, 90.28, 90.35, and 90,09 dBA for 15, 30, 45, and 60 Nm loads, respectively. As seen in Figure 13, the noise level decreases up to 45 Nm and increases at 60 Nm. This can be attributed to the fact that the increased combustion chamber temperature due to engine load decreases the ignition delay time and increases the combustion efficiency. At 60 Nm, the increase in combustion duration due to the maximum amount of fuel injected also increased the noise level.

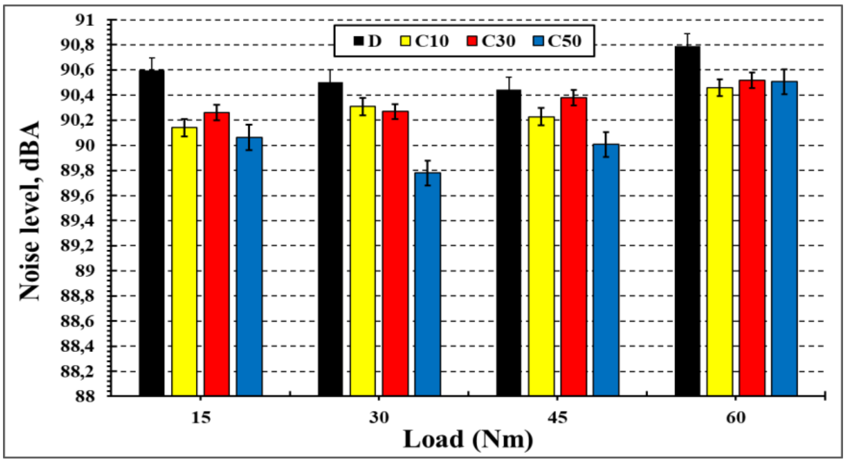

Figure 13. *The noise levels of the test fuels as a function of engine load.*

IV. CONCLUSION

The biodiesel fuel used in this study was produced from refined canola oil. The produced canola oil methyl ester was mixed with conventional diesel fuel at different ratios by volume to obtain test fuels. The following results were obtained for the combustion, noise, and vibration characteristics of canola biodiesel and its blends compared to conventional diesel fuel in a three-cylinder engine using a mechanical fuel injector.

- The highest maximum in-cylinder pressure values for all test fuels were obtained at 15 Nm.
- At 15 Nm, the maximum in-cylinder pressure and HRRmax values heightened subject to the biodiesel content in the test fuels.
- As a consequence of the combustion caused by each injector injecting fuel, 50 vibration amplitude zones are generated in 1 second.
- The average a_{RMS} values for all test fuels are 4.9, 4.5, 4.17, and 4.83 m/s2 for loads of 15, 30, 45, and 60 Nm, respectively.
- For all test fuels, the largest vibration value was obtained at 15 and 60 Nm and the smallest vibration value was obtained at 45 Nm.
- The largest aRMS values were obtained with conventional D fuel and the smallest aRMS values with C50 fuel at all loads.
- The highest noise level was obtained with conventional fuel D at all engine loads. The addition of biodiesel to the test fuels reduced the noise level at all loads.
- The engine noise level is reduced up to 45 Nm and increased at 60 Nm.

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