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Experimental investigation of the effects of 7% ethanol and 7% isopropanol added to standard diesel fuel on engine vibration and noise

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Abstract – Reducing noise and vibration emissions, which are the most important factors affecting driving comfort in diesel engine vehicles, is an important issue. It seems possible to reduce these emissions by adding renewable fuels to diesel fuel. The main purpose of this study is to reduce engine vibration and noise emissions by mixing ethanol and isopropanol fuels with diesel fuel. In the experimental study, 7% ethanol (D93E7) and 7% isopropanol (D93IP7) were added to the pure diesel fuel to reduce vibration and noise emissions caused by the use of standard diesel (D100) fuel. The experiments were carried out at two different loads (3-6 Nm) and at four different speeds (1000-1500-2000-2500 rpm). When the test results are evaluated in general; In the tests performed with D93E7 fuel at 6 Nm load and 2000 rpm, it was determined that vibration emissions decreased by 26% compared to D100 fuel and noise emissions decreased by 2%. On the other hand, in tests performed at low load (3 Nm) with D93IP7 fuel, it was determined that vibration and noise emissions were lower than D100 and D93E7 fuels.

Keywords – Diesel, Ethanol, Isopropanol, Vibration, Noise

I. INTRODUCTION

Diesel engines are preferred because of their high energy efficiency. However, the high compression ratio of these engines increases vibration and noise emissions. The increase in vibration and noise adversely affects driving comfort. This situation has negative effects on living things [1, 2]. Legal regulations aimed at reducing the negative effects of vehicles have been enacted by the European Union countries. In the European Union countries, compliance with the 540/2014/EU regulation is mandatory in order to reduce the negative effects of noise emissions on human health [3]. This regulation imposes a limitation on the sum of vehicle noise. However, the main source of noise is known as diesel engine, especially in vehicles with diesel engines. Studies to reduce diesel engine noise have increased in importance in recent years [4]. On the other hand, the fact that these values are high is also important for the health of the internal combustion engine operating for a long time [5, 6]. Vibration and noise emissions of diesel engines can be reduced by changes in fuel chemistry instead of structural changes. At the same time, the addition of biofuels to diesel fuel is also very important to create an alternative to petroleum. Since the mixing ratios of biofuels with diesel fuel affect the combustion performance, it is an important issue to adjust the mixing ratio correctly. From biofuels, biodiesel has been used with diesel fuel for a long time. On the other hand, the addition of alcohols to diesel fuel is very effective in improving the properties of diesel fuel. The low cetane number of the alcohol mixtures used affects the combustion feature of the fuel and is effective in reducing vibration and noise by providing a more controlled combustion [7].

Alcohol blends with diesel fuel have been used in studies to improve engine performance and emissions. For example, Ciniviz et al. (2022) found that vibration emissions were reduced by approximately 25% in their experiments by adding 5% ethanol, isobutanol and isopropanol to diesel fuel [8]. Şanlı (2023) added isopropanol, heptanol and butanol to diesel fuel in his experimental study on a common rail diesel engine. When the study data is evaluated in general, it has been determined that alcohol mixtures give better results in cyclic combustion changes [9]. In their study, Kesharvani et al. (2023), in their experimental study by adding biodiesel and ethanol to pure diesel, determined that the addition of ethanol has a higher combustion performance [10]. Vargun et al. (2022) experimentally investigated the engine performance and emission outputs of ethanol butanol and diesel fuel mixtures. In the test results, they found an increase in engine noise with alcohol mixtures. However, they found that the increase in the ethanol ratio increased the ignition delay time [11]. Ağbulut et al. (2020) found that the highest vibration occurred in 10% biodiesel blended fuel in their experiments with biodiesel and various metal oxide-based nanoparticle blended fuel. They determined that the addition of nanoparticles reduces vibration [12]. Dolores Redel-Macías et al. (2021), they found that the addition of ethanol and propanol to diesel fuel is effective in reducing engine noise emissions. Researchers have stated that the main reason for this is due to the long carbon chain structure of alcohols [13]. Taghizadeh-Alisaraei and Rezaei-Asl (2016), who examined the effect of adding ethanol to diesel fuel on engine vibration, found that with the addition of 6% ethanol, engine torque increased and there was an increase of approximately 8% in engine vibration [14]. In another study examining the effect of butanol addition to diesel fuel on engine vibration and noise Morgül (2021) found that 10% butanol addition reduced engine noise up to 3 dBA [15]. Studying the effects of diesel, biodiesel and alcohol blends on engine performance and vibration properties, Jaikumar et al. (2020) declared that the minimum vibration data were obtained in the experiments performed with the addition of 1% isobutanol to B20 fuel [16]. By adding alcohols to diesel fuel, the properties of the fuel can be improved. When the studies are examined in general, the main purpose is to provide improvements in engine performance and emissions. The second aim of the studies is to identify usable biofuels and to create an alternative to petroleum.

In this study, unlike previous studies, the focus is on diesel engine noise and vibration emissions. In experiments; Engine tests were carried out with standard diesel (D100), 7% ethanol added diesel (D93E7) and 7% isopropanol added diesel (D93IP7) fuels. The tests were carried out at two different loads (3-6 Nm) and at four different speeds (1000, 1500, 2000, 2500 rpm). In the tests, the noise and vibration data generated by the engine were recorded and evaluated. The main purpose of the study is to reduce diesel engine vibration and noise by using a small amount of alcohol mixture.

II. MATERIALS AND METHOD

A. *TEST ENGINE*

The experiments were conducted using an ANTOR AD 320 model single-cylinder diesel engine, as shown in Figure 1. The technical specifications of the engine are provided in Table 1.

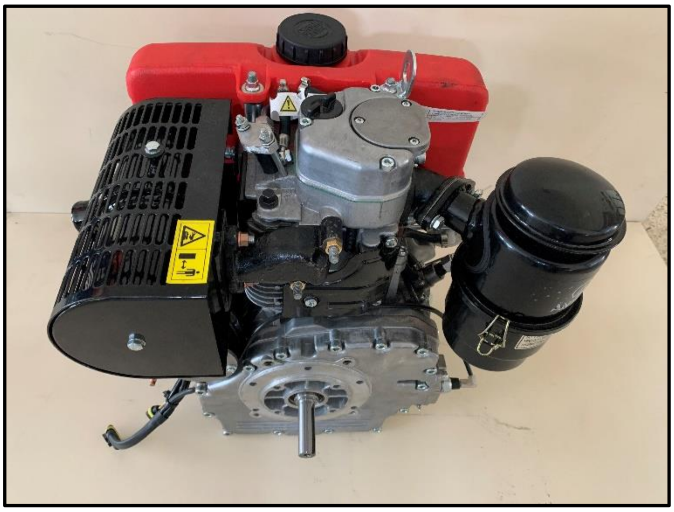


Fig. 1. Single cylinder test engine

Table 1. Engine specifications [20]

Brand/Model	ANTOR / AD 320
Number of cylinders	1
Cylinder volume	315 cm^3
Cylinder diameter	78 mm
Stroke	66 mm
Compression ratio	17,5/1
Engine speed	3600 rpm
Max. torque	10,5 @1850 rpm
Crankcase oil capacity	1,2 lt
Injection timing	20 [°CA bTDC]
Injection pressure	220 [Bar]

B. *DYNAMOMETER*

The dynamometer used in the experiments was an ABB brand air-cooled active dynamometer, as depicted in Figure 2. It is capable of operating in four different modes. The technical specifications of the dynamometer are presented in Table 2.

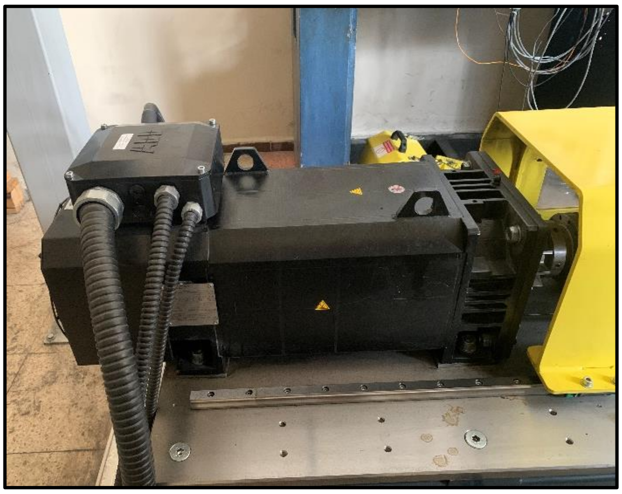


Fig. 2. Dynamometer

Table 2. Dynamometer technical specifications [21]

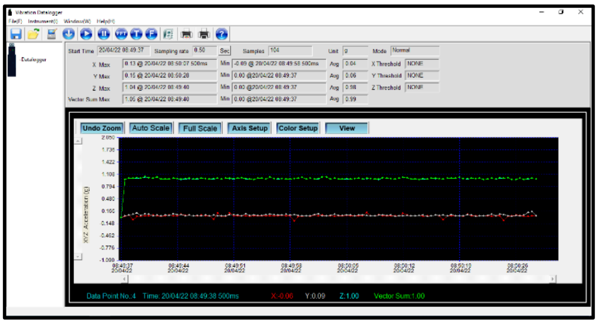
Brand/Model	ABB/Square body
Rated power (kW)	49,3
Rated speed (rpm)	3000
Rated torque (Nm)	157
Maximum speed (rpm)	7500
Power factor	0,831
Yield (%)	93,6

The speed measurement was conducted using a 1024 ppr HTL encoder connected to the shaft of the dynamometer.

C. *VIBRATION DEVICE*

A vibration device was used to measure the oscillation created by the diesel engine. The PCE-VD3 model accelerometer vibration device seen in Figure 3a was used to record the data. This device is a miniature universal data logger with an integrated three-axis (X, Y, Z axes) acceleration sensor. The built-in sensor in this device is capable of measuring within ± 18 measuring ranges per axis. It measures the total resultant acceleration in three (X, Y, Z) axes and in four different acceleration (g) units. All data were recorded automatically with the computer interface shown in Figure 3b at a time interval of 500 ms. Data were recorded over a 100 second period.

(a)



(b)

Fig. 3. Vibration device (a) and computer interface (b)

The vibrator device is attached to the cylinder block of the engine. Fig. 4. It is fixed so that it does not move independently as seen. The device was connected to the computer with a USB cable and the data were recorded with software.

Fig. 4. Connection of the vibration device on the engine

D. NOISE DEVICE

The noise generated by the engine was measured with the GERATECH DT 8820 sound level meter, shown in Fig. 5. Values are determined in decibel dB(A). Noise measurements were recorded at a distance of 1.0 meter from the noise center in accordance with the ISO 362-1:2007 standard [17]. Since the measurements are made indoors, the only source of noise is the engine.

Fig. 5. Noise meter

E. TEST FUELS

The physical and chemical properties of the test fuels are given in Table 3. Standard diesel fuel (D100) was used as the main fuel. The second fuel was obtained by mixing 93% standard diesel and 7% ethanol by volume (D93E7). The third fuel was obtained by mixing 93% standard diesel and 7% isopropanol by volume (D93İP7).

Table 3. Physical and chemical properties of test fuels[18,19]

Properties	Diesel	Ethanol	Isopropanol
Mol. formula	C_nH_m	C_2H_5OH	C_3H_7OH
Mol. wt. (Kg/kmol)	185-212	46.06	60.1
Density (kg/m^3)	830-840	788	800-805
Cetane num.	45-52	5-15	10-12
Viscosity at 40^{o}C (m/s^2)	0.0027	0,00012	0.0017

III. RESULTS AND DISCUSSION

The experimental parameters are provided in Table 4. The tests were conducted at two different loads (3 and 6 Nm) and four different speeds (1000, 1500, 2000, 2500 rpm). Ambient pressure and temperature were recorded during the operation, as these parameters can affect the engine's operating performance.

Table 4. Experiment parameters

Engine speed (RPM)	1850
Engine oil temperature (ºC)	>70
Ambient temperature (ºC)	16
Ambient pressure (bar)	0,89
Ambient humidity (% Rh)	25,87
Injection pressure (bar)	220
Injection time (bTDC)	20º
Engine load (Nm)	3,6
Engine speed (rpm)	1000,1500,2000,2500

The test results were evaluated by visualizing them with graphics. Figure 6 illustrates a comparison of the noise emissions of standard diesel, D93E7 fuel, and D93IP7 fuel at a 3 Nm load.

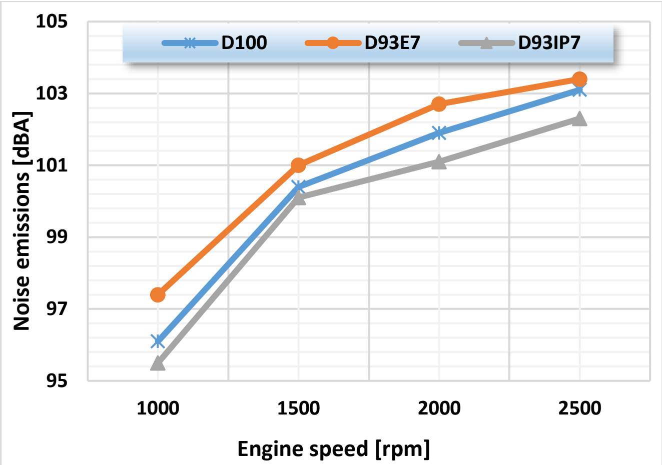


Fig. 6. Effect of standard diesel, D93E7 fuel, and D93IP7 fuel on noise emissions at 3 Nm load and different speeds.

According to experimental data, noise values increase with increasing engine speed. The main reason for this situation is that as the rpm increases, the amount of fuel sent by the fuel system increases and it creates a knock. At the same time, D93IP7 fuel was found to be effective in reducing engine noise. This may be due to the fact that the cetane number of isopropanol is higher than that of ethanol. The engine noise data generated in the experiments performed with the same fuels at 6 Nm load are shown in Figure 7.

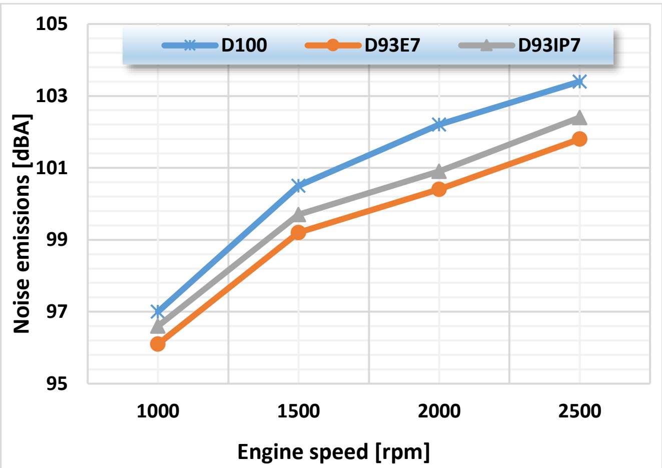


Fig. 7. Effect of standard diesel, D93E7 fuel, and D93IP7 fuel on noise emissions at 6 Nm load and different speeds.

In the tests performed at 6 Nm load, it is seen that the measurement values made with D93E7 fuel are lower than the other two fuels. The test results obtained were evaluated by visualizing them with graphics. The vibration emissions of standard diesel, D93E7 fuel, and D93IP7 fuel at 3 Nm load are shown in Figure 8 comparatively.

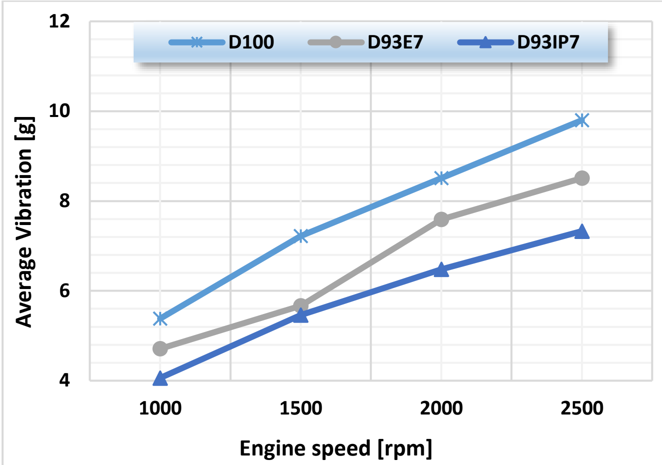


Fig. 8. Effect of standard diesel, D93E7 fuel, and D93IP7 fuel on vibration emissions at 3 Nm load and different speeds.

Vibration emissions with D93IP7 fuel compared to D100 fuel;

- It decreased by 24.5% in 1000 cycles.
- It decreased by 24.3% at 1500 cycles.
- It decreased by 23.8% in 2000 cycles.
- It decreased by 25.2% at 2500 cycles.

The addition of ethanol and isopropanol to diesel fuel was effective in reducing engine vibration emissions. It is clearly seen that D93IP7 fuel is more effective at low loads. The engine vibration data generated in the experiments performed with the same fuels at 6 Nm load are shown in Figure 9.

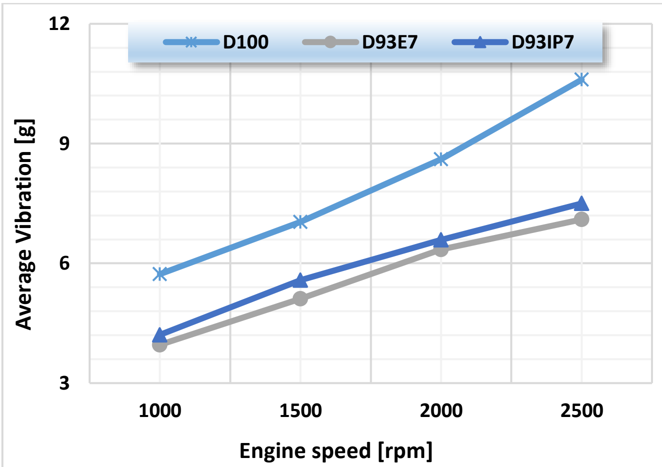


Fig. 9. Effect of standard diesel, D93E7 fuel, and D93IP7 fuel on vibration emissions at 6 Nm load and different speeds.

Vibration emissions with D93E7 fuel compared to D100 fuel;

• It decreased by 30,9% in 1000 cycles.
• It decreased by 27,4% at 1500 cycles.
• It decreased by 26,2% in 2000 cycles.
• It decreased by 33% at 2500 cycles.

The average vibration data was also in line with the noise emissions. At low loads, D93IP7 fuel was more successful in reducing vibration emissions, while D93E7 fuel was more effective in reducing vibration with load increase.

IV. CONCLUSION

In this study, engine noise and vibration emissions of standard diesel fuel, 7% ethanol blended diesel fuel (D93E7), and 7% isopropanol blended diesel fuel (D93IP7) were investigated. When all data are evaluated;

- When the noise emissions are evaluated, the D93E7 fuel caused the noise to increase at low load, while effectively reducing the noise emissions at high load.
- While D93IP7 fuel is effective in reducing noise emissions at low load, this effect is reduced at high loads.
- Data on vibration emissions are in parallel with noise emissions.
- D93E7 fuel has shown great success in reducing vibration emissions at high load, while reducing the load has reduced this effect.
- D93IP7 fuel has considerably reduced vibration values at low load. The effect decreased with increasing load.

Future studies, studies can be carried out to reduce noise and vibration emissions by trying different ratios or multiple mixtures in mixing ratios.

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