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Research Article

The Investigation of Performance And Emission Characteristics Of Waste Transmission Oil On A Diesel Engine

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ABSTRACT

Environmental issues such as ever-increasing energy demand, declining fossil fuel deposits, global warming and higher levels of air pollution necessitate the transition to renewable fuels. It is necessary to develop a cleaner, safer, sustainable and renewable alternative for fossil fuels. For the production of such fuels using thermochemical processes, it is important to use products with a fuel potential in a waste state. In this context, it is proposed to convert waste transmission oil. Accordingly, in the study, Diesel-like fuel was obtained from waste transmission oil through the pyrolysis method. The fuel produced is a mixture of diesel with waste transmission oil, 80% diesel and 20% waste transmission oil. Engine tests were carried out with the use of the produced mixture fuel and pure diesel fuel in a diesel generator engine and the necessary comparisons were carried out. Performance and emission tests were carried out in the study. Compared to diesel fuel, an increase of 4% in thermal efficiency at low loads and an increase of 2.5-3% in specific fuel consumption was determined. The NO_X emission of blended fuel is much higher than diesel fuel at all loads. The change with increasing load is limited to 18.5-25%. A 25% reduction in HC emissions was observed. According to the test results obtained, it can be said that the waste transmission oil-doped mixture fuel produced can be used instead of diesel fuel for its intended purpose.

1. INTRODUCTION

Environmental issues such as ever-increasing energy demand, decreasing fossil fuel deposits, global warming and higher levels of air pollution; require the transition to renewable fuels. Engineering studies; aim to develop a cleaner, safer, sustainable and renewable alternative to fossil fuels. In the process, it is important to use wastes that can be converted into fuel. In this regard, it has been proposed to convert waste transmission oil to produce such fuels using thermochemical processes [1].

Production of various fuels; thermochemical conversion, torrefaction, pyrolysis and gasification etc. possible by using various methods [2]. Fast pyrolysis, it is considered an important route as it results in a high energy density diesel fuel. These diesel fuels, oil products that are not suitable for use, etc. can be produced from fuels [3]. Thus, the abundance of raw materials suitable for the fuel production process, promotes thermochemical transformations.

Carbon and hydrogen, it forms the origin of diesel fuel, like most fossil fuels. For ideal thermodynamic equilibrium, a full combustion of diesel fuel will only produce CO_2 and H_2O in the engine combustion chambers [4]. However, many reasons (air-fuel ratio, ignition timing, turbulence in the combustion chamber, combustion form, air-fuel concentration, combustion temperature, etc.) make this impossible and a number of harmful products are produced during combustion. The most important harmful products are CO, HC, NO_x and Particulate Matter (PM).

Any mineral oil or synthetic oil becomes chemically and physically contaminated and loses its originality after a certain period of use in industrial or non-industrial areas. These types of oils cannot perform well due to long usage over time. In this direction, it is preferred to replace used oils with new oils in order for the engine to work better.

On the other hand, waste oils have eco-toxic properties, pollute the environment they are in and harm all living organisms in the environment. It is forbidden to dispose of them in places such as stoves or small ovens. The reason for this is that the heavy metal and chlorine compounds in the waste oil are released into the atmosphere together with the waste air, polluting the air and harming human health.

Arpa et al. [5] conducted an experimental study on diesel-like fuel (DLF) for engine performance and exhaust emission change. In the study, it was observed from the test results that approximately 60 cc of waste oil was converted to DLF from every 100 cc of waste oil. This result showed that the produced DLF can be used in diesel engines without any problems in terms of engine performance. DLF increased torque, brake average effective pressure and brake thermal efficiency, and also reduced the brake-specific fuel consumption of the engine for full operating power.

In addition to the information given above, we can mention that the properties of fuels and distillation temperatures are other effects on performance parameters [6]. Obviously, these properties lead to the fact that fuels give better mixing and combustion properties and reduce heat loss Because lower distillation temperatures ensure better performance results [7].

İlkılıç and Aydın [8] conducted an experimental study on an alternative fuel obtained by pyrolysis of waste vehicle tires. In the study, pure diesel, pure tire pyrolysis oil and their mixtures in different fractions were used. At the end of the study, it was determined that the power values of all fuel mixtures of pyrolysis fuel and diesel fuels showed increasing trends according to the increase in engine speed.

Pyrolysis is the thermochemical decomposition of organic matter caused by heat, in the absence of oxygen or any other reagent. During the pyrolysis process, large complex hydrocarbon molecules are converted into different smaller molecules of gas, liquid and coal. While temperatures of 450 °C and above are preferred for obtaining liquid products, lower temperatures are preferred for liquid production. Although the pyrolysis liquid has a dark color, it may vary depending on the sample used and its content [9]. The processed raw material enters the reactor, where it is heated up to the pyrolysis temperature (maximum temperature) at which decomposition will begin. The next stage is when the condensable and non-condensable vapors released from the feedstock leave the compartment. Although the vast majority of the solid coal produced remains in the compartment, a small part of it also remains in the gas. The next stage is to separate the gas from the coal and cool the downstream of the reactor. The final stage is the condensation of the condensable steam as pyrolysis oil, it is the process of separating the non-condensable steam from the reactor as product gas. In this process, solid coal is collected as a commercial product or used as a combustible to produce the heat necessary for pyrolysis [10].

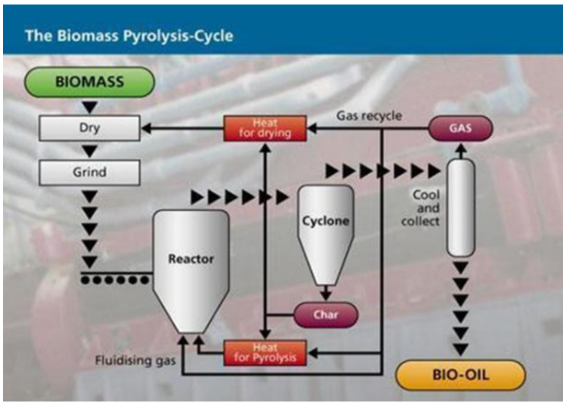

Figure 1. Pyrolysis Cycle [Abnisa and Wan Daud, 2014]

The most important products to be obtained by pyrolysis method are liquid products. Because liquid products can be an important substitute for fossil fuels, the nature of which depends on different parameters. The factors mentioned are; the type of raw material used in the process, temperature depending on the characteristics of the raw material, heating rate, reaction time and the particle size of the feed. The parameters affecting the pyrolysis process at this point are the type of raw material used in the process, the temperature which depends on the characteristics of the raw material, heating rate, reaction time and particle size of the feed [11].

2. MATERIALS AND METHODS

In this research, fuel obtained from waste transmission oil by pyrolysis method and pure diesel fuel were used in a single cylinder generator engine as a mixture. Volumetric ratios of diesel and mixed fuel are given in Table 1.

TABLE I
VOLUMETRIC RATIOS OF DIESEL AND DIESEL-LIKE FUEL

	Volumetric Percentage of Diesel Fuel	Volumetric Percentage of Waste Transmission Oil
D80WTO20	80	20
DIESEL	100	0

Table 2 provides information about the chemical and physical properties of the fuels to be used in the experiments.

TABLE II
THE DETERMINATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF FUELS TO BE USED IN DIESEL ENGINE EXPERIMENTS

Properties	DF	Pyrolytic Fuel
Density (gr/cm^3)	0,830	0,860
Viscosity (mm^2/sn)	2,90	3,60
Flash Point (ºC)	60	51,5
Lower Thermal Value (kj / kg)	43200	40400
The Amount of Sulfur (ppm)	50	>1000
Cetane Number	53	48

A schematic representation of the experimental setup created for the study is given in Figure 2.

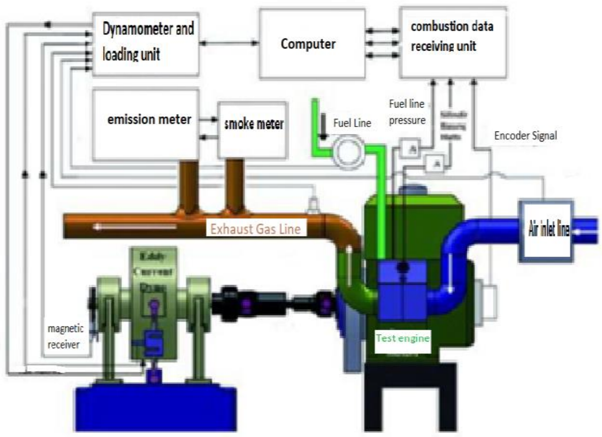

Figure 2. Schematic Representation of the Experimental Setup

3. RESULTS AND DISCUSSIONS

At the point of meeting the increase in energy demand which is an increasing value every day, we are faced with two options. The first is to find new renewable energy sources. The second is to obtain fuel from waste. In order to serve this purpose in the study, waste transmission oils (WTO), which pollute the nature, have been converted into a form that can be used in engines. After that, combustion, performance and emission tests were performed. Two types of fuel were used in the experiments. These fuels have been subjected to engine tests under 3 different loads. These loads are respectively; no load, 5 kg and 10 kg. At the end of the study, the engine test results of two different fuels under different loads.

3.1. Statistical analysis

In order to better confide on the measurement data from the experimental engine, this section of the paper has been presented. The confidence level of 0.95 or α=0.05, standard error, means and confidence intervals of the test values of the test engine operated with varied test fuels are included in Table III for emissions and in Table 4 for engine performance that contains statistical analysis parameters. For all experiments, the target level of test confidence was 95%. The test findings include standard error and mean those were computed. These data were used to compute the confidence intervals, which are displayed in Table III and Table IV as the level of deviation from means for each parameter of the applied tests. The experimental data points' confidence intervals are calculated by subtracting and adding the confidence from the mean values. It is simple to conclude that the confidence intervals and other statistical parameters for the chosen confidence levels are significant and well-concordant, indicating that the used tests parameters are quite stable and reliable.

TABLE III

THE STATISTICAL ANALYSIS PARAMETERS OF EXPERIMENTAL POLLUTANT EMISSION INDICATORS

		D100	D80WTO20
CO	Confidence Level	0.05	0.05
	Standard Error	0.01	0.01
	Number of Experiments	3.00	3.00
	Mean Values	0.02	0.02
	Confidence interval	0.01	0.01
CO_2	Confidence Level	0.05	0.05
	Standard Error	0.55	0.65
	Number of Experiments	3.00	3.00
	Mean Values	1.27	1.57
	Confidence interval	0.62	0.74
HC	Confidence Level	0.05	0.05
	Standard Error	0.58	1.73
	Number of Experiments	3.00	3.00
	Mean Values	11.3	7.00
	Confidence interval	0.65	1.96
NOx	Confidence Level	0.05	0.05
	Standard Error	95.7	132.5
	Number of Experiments	3.00	3.00
	Mean Values	126	146
	Confidence interval	108	150

TABLE IV

THE STATISTICAL ANALYSIS PARAMETERS OF EXPERIMENTAL PERFORMANCE INDICATORS

		D100	D80WTO20
η_{th} (%)	Confidence Level	0.05	0.05
	Standard Error	22.18	21.70
	Number of Experiments	3.00	3.00
	Mean Values	26.94	26.43
	Confidence interval	25.10	24.56
Be (gr/kWh)	Confidence Level	0.05	0.05
	Standard Error	147.64	143.95
	Number of Experiments	3.00	3.00
	Mean Values	458.63	466.12
	Confidence interval	167.06	162.89
η_e (%)	Confidence Level	0.05	0.05
	Standard Error	0.55	0.65
	Number of Experiments	3.00	3.00
	Mean Values	1.27	1.57
	Confidence interval	0.62	0.74

3.2. Performance Parameters Tests

Equivalent heater resistance groups were used to draw energy from the engine generator group. In order to determine the engine performance parameters in the experimental setup, fuel consumption values were taken from precision scales. For this purpose, 1-minute fuel consumption values were determined in order to stabilize the engine operating conditions during fuel changes, and the average value obtained was accepted as kg/h fuel consumption value with the formula below. The performance characterizes of both fuels are analyzed and depicted in Fig. 3.

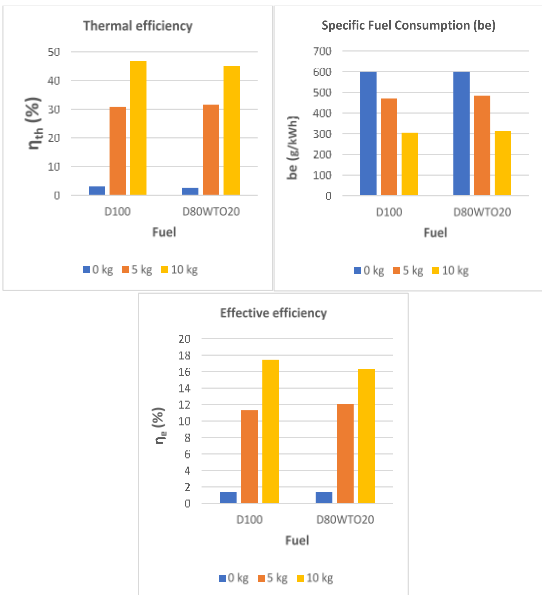

Figure 3. Performance Parameters of fuels

The ŋ-thermic values of the blended fuel compared to the diesel fuel were found to be very close to each other for all loads. In both types of fuel, the values in the unloaded state are quite low compared to the ŋ-thermic values in other loads. In addition, as the amount of load increased in both fuels, their ŋ-thermic values have also increased. In other words, a direct proportion was found between them.

Specific fuel consumption is expressed as the value in grams (g/kWh) of the fuel that the engine should consume per kWh of work in stable operation. As can be seen, the highest specific fuel consumption was recorded in the no-load condition. As the load amount increased, the specific fuel consumption was decreased. In other words, an inverse proportion was observed between them. In addition, the specific fuel consumption of blended fuel is slightly higher than that of diesel. Specific fuel consumption is an important parameter for determining performance in engines and can be defined as the amount of fuel that must be spent to obtain unit power. There is higher specific fuel consumption compared to diesel since the heating value decreases in the use of the mixture.

The effective efficiency is described as the ratio of the work received from the motor shaft to the total energy delivered. The thermal values of the fuels used in the experiments are given in Table V.

TABLE V

THERMAL VALUES OF THE FUELS USED IN THE EXPERIMENTS

Fuel	Thermal Value (kJ/kg)
Diesel	42700
Waste Transmission Oil	41500

According to the data, the effective efficiency increased as the load amount increased in both types of fuel. The effective efficiency in the no-load state is quite low compared to the conditions under load. The effective efficiency of the blended fuel is close to that of diesel. However, with the increase in load, partial reductions have appeared, depending on the development of the combustion process, its duration and thermal value.

3.3 Emission Tests

The emission characterizes of both fuels are analyzed and depicted in Fig. 4. Oxygen emission has been measured as a percentage by volume of the total air expelled from the exhaust. As the speed of the test engine operated with diesel fuel is increased, the amount of oxygen emitted from the exhaust also decreases. It is thought that the reason for this is the combustion efficiency of the parameter. When there is a lack of oxygen in combustion, carbon (C) does not burn sufficiently. When the speed is increased, the amount of fuel that needs to be burned per unit time and the amount of O_2 that will be used in the combustion reaction will also increase. Therefore, due to the increase in speed, the amount of oxygen needed in the face of fuel has increased. Thus, the amount of oxygen entering into the reaction also has increased. In this respect, it is thought that the O_2 released from the exhaust decreases. The amount of oxygen emitted by diesel and D80WTO20 fuels from the exhaust has been obtained inversely proportional to the increase in the amount of load. In other words, as the amount of load increased, the amount of O_2 released has decreased. As can be understood from here, it can be said that the combustion efficiency is well realized.

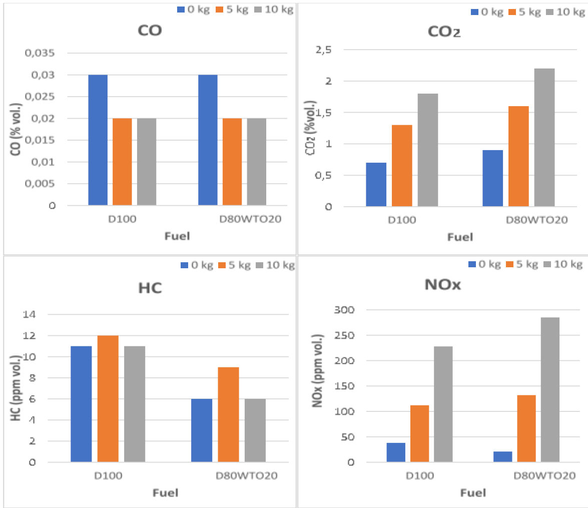

Figure 4. Emission formation of fuels

Carbon monoxide (CO), when taken too much into the human body, sticks to hemoglobin, reducing the oxygen carrying capacity of the blood. In the brain and heart, which are the basic organs of life, functional disorders occur due to oxygen deficiency. For this reason, it is not desirable that the amount of CO in vehicle exhaust waste is excessive. As can be seen in the given graph, CO emissions has decreased for both fuels depending on the increase in the load. CO emissions are greatest at no load. In other loads, the CO release is the same amount. In addition, the emission amounts of both fuels has given the same result. While the highest CO emission is 0,03 %vol, other emission amounts are 0,02 %vol. However, emissions are at an acceptable level in both these fuel samples. High temperature, incomplete air and incomplete combustion have increased the amount of CO at low speeds.

Carbon dioxide (CO_2) is odourless, colorless and tasteless. CO_2 does not appear as a toxic gas, but when it exceeds 30%, it causes damage to breathing [12]. Depending on the load increase in both fuel types, an increase in CO_2 emissions was observed. However, the amount of CO_2 emission of D80WTO20 fuel was found to be more than diesel in each load amount. As the load amount increases, the better the combustion has given off due to increased air movements. In addition, combustion at low loads gave a better result. In this case, while the amount of CO decreased, it has caused an increase in CO_2. The increase in CO_2 emissions can be explained by the improvement of combustion and therefore the conversion of more CO to CO_2.

Hydrocarbons (HC) are unburned fuel components that arise as a result of an irregular reaction in which combustion does not occur to the desired extent. These components, which can come out of the exhaust in different forms, have negative effects on human health, such as cancer [13]. While a decrease is expected in the number of carbons released from the cylinder with a good combustion, an increase in the number of carbons is expected in the exhaust with a bad combustion. While the increase in the amount of HC continued, it was determined that the amount of HC in diesel fuel was higher. The D80WTO20 is more efficient than diesel in terms of the amount of HC. It can be said that the reason for the high level of HC emissions is insufficient combustion. It has been shown that the reason why fuels produce high HC emissions is that the thickness of the extinction zone increases due to low temperature.

Internal combustion engines powered by diesel fuel account for more NO_x than gasoline engines. Nitrogen oxides are released due to engine operation under high temperature conditions [14]. The main reason for this is that diesel fuel needs more air for combustion. During combustion, nitrogen (N_2) and oxygen (O_2) combine at high temperatures to form Nitrogen oxides (NO_x). Arpa et al. [15] in the study of, NO emissions of diesel-like fuels were higher than diesel. NO_X values are highest at the moment when the weight was highest. Figure 6 was shown data on NO_x emissions of nitrogen oxides. Accordingly, the NO_X emission of the blended fuel is much higher than that of diesel fuel at all loads. When D80WTO20 fuel was examined, it was seen that NO_X emissions increased in direct proportion with increasing the load amount. It can be said that at low speeds, poor combustion occurs due to excessive load and insufficient air. The temperature increase due to the load has increased the amount of NO_X. Evaporation of fuel depends on its properties, such as its interaction with air and viscosity. All these factors affect the spray advance, ignition delay, pre-combustion and flame spread, that is the formation of NO_x as a result.

4. CONCLUSIONS

As a result of the conducted experimental research, the following conclusions were reached:

- As a result of the pressure increase rate test; as the load amount increased, the characteristic similarity of the fuel types increased. With the increase in the load amount, the pressure increase rate also has increased.

- The cumulative heat release between fuels has differed depending on the content of the fuels. The cumulative heat release for the D80WTO20 has steadily increased as the amount of load has increased. But it consistently has a lower cumulative heat release value than diesel fuel. The heat release for D80ASY20 is close to 90% of the diesel fuel value. The reason for this situation is that the emulsified mixture contains low heat.

- As the load amount increases, the cylinder pressure increases. The cylinder pressure in diesel fuel has always given more results than in D80WTO20 fuel.

- It is observed that the specific fuel consumption of D80WTO20 fuel is higher than diesel fuel. The change is limited to 2.5-3%.

- It has been determined that the amount of oxygen released from the exhaust of the D80WTO20 fuel mixture is inverse with the increase in the load it carries. It can be said that an efficient combustion has taken place.

- With the increase in the load amount, the CO emission decreased for the blended fuel.

- It has been observed that CO_2 emissions increase in diesel and blended fuels with the increase in the load amount. However, compared to diesel fuel, the CO_2 emission of the blended fuel is lower.

- Since hydrocarbons (HC) enter the combustion reaction at desired levels, the amount of O_2 and HC discharged from the exhaust is lower than diesel fuels. The change is limited to 25%.

- The NOX emission of blended fuel is much higher than diesel fuel at all loads. At low speeds, it can be said that poor combustion occurs due to overload and insufficient air. The change with increasing load is limited to 18.5-25%.

Due to the excess of waste transmission oil, using it instead of fuel will be beneficial for both the environment and fuel economy.

REFERENCES

[1] Roy, P. ve Dias, G. Prospects for pyrolysis technologies in the bioenergy sector: A review, Renew. Sustain. Energy Rev. 77 (2017) 59–69.
[2] Bridgwater, T. Biomass for energy, J. Sci. Food Agric. 86 (2006) 1755–1768.
[3] Sipra, A.T. Gao,N. Sarwar,H. (2018). Municipal solid waste (MSW) pyrolysis for bio-fuel production: A review of effects of MSW components and catalysts, Fuel Process. Technol. 175 (2018) 131–147.
[4] Prasad R, Bella VR (2010) A review on diesel soot emission, its effect and control. Bull Chem React Eng Catal 5(2):69–86
[5] Arpa O, Recep Y, Zeki A Experimental investigation of the effects of diesel-like fuel obtained from waste lubrication oil on engine performance and exhaust emission. Fuel Process. Technol. 91:1241-1249 (2010a).
[6] Koç M, Sekmen Y, Topgul T, Yucesu HS (2009). The effect of ethanoleunleaded gasoline blends on engine performance and exhaust emissions in a sparkignition engine. Renew. Energy 34:2101-2106.
[7] Al-Ghouti MA, Al-Degs YS, Amer M (2008). Determination of motor gasoline adulteration using FTIR spectroscopy and multivariate calibration. Talanta 76:1105e12.
[8] İlkılıç, C., Aydın, H. Fuel production from waste vehicle tires by catalytic pyrolysis and its application in a diesel engine, Fuel Processing Technology, 2011 – Elsevier.
[9] Uyar M, Aydın H; Production of low sulfur diesel-like fuel from crude oil wastes by pyrolytic distillation and its usage in a diesel engine. Energy, Volume 244, Part A, 1 April 2022, 122683
[10] Basu, P. Biomass gasification, Pyrolysis and Torrefaction, Second Edi. 2013.
[11] Abnisa F. and W. M. A. Wan Daud, "A review on co-pyrolysis of biomass: An optional technique to obtain a high-grade pyrolysis oil," Energy Convers. Manag., vol. 87, pp. 71–85, Nov. 2014.
[12] Ayaz, M. E. (2003). Hacıali ve Karayün (Sivas) Çevresinin Jeolojisi ve DoğalKarbondioksit Potansiyeli. FÜ Fen ve Mühendislik Bilimleri Dergisi, 15(4), 523-538.
[13] Aydoğan, H. (2006). Dizel Motorlarında Çeşitli Yakıt Enjeksiyon Sistemlerinin EgzozEmisyonlarına Etkilerinin Deneysel incelenmesi. Yüksek Lisans Tezi, Gazi Üniversitesi,Ankara.
[14] Hanbey H, Uyar M, Aydın H; The Effects of Apricots Seed Oil Biodiesel with Some Additives on Performance and Emissions of a Diesel Engine. International Journal of Automotive Engineering and Technologies Vol. 5, Issue 3, pp. 102 –114, 2016
[15] Arpa O, Yumrutas R, Alma MH Effects of turpentine and gasoline-like fuel obtained from waste lubrication oil on engine performance and exhaust emission. Energy 35:3603-3613, (2010b).

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