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Preparation of Alternative Fuel from Waste Transformer Oil and Studying Performance Characteristics on Diesel Engine for Different Blends

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ABSTRACT:

Reuse and recycling are better option to derive energy or value added products from waste substances and to minimize the disposal problems. Transformer oil is generally used as a coolant in welding transformers, power transformers and electromotive units. After prolonged use in this device, the transformer oil becomes waste and disposed of. The disposal of waste transformer oil (WTO) causes an environmental pollution. However, the WTO has properties that are similar to diesel fuel with marginally higher viscosity and lower calorific value. The present investigation is aimed to reuse the WTO as a possible source of energy to run a small powered, single cylinder water cooled diesel engine. In the present work, three different blends of waste transformer oil in varying proportions of 10%, 20%, 30% with diesel are used. The performance parameters such as a brake power, specific fuel consumption, and thermal efficiency are calculated on experimental analysis of engine. The results are analyzed and compared with diesel operation of the same engine.

Keyword: waste transformer oil, engine performance, efficiency, properties of WTO

1. INTRODUCTION:

An engine is a device that transforms one form of energy into another form. While transforming energy from one form to another, the efficiency of conversion plays an important role. Heat energy is a device that transforms the chemical energy of fuel into thermal energy and utilizes thermal energy to perform useful work. Thus, thermal energy is converted into mechanical energy in heat engine. Increase in automobile indicates that there will be great demand for the fuel in future. India imports most of the fuel from middle east. India imports approximately 34% millions ton of crude oil each year. The energy consumption in terms of oils and other energy sources is growing drastically, and it is increase in the world by 36% in the year 2035. The growing demand is caused by an exponential increase in the population that predicted to increase further by 25% in the next 20 years, with major population increases particularly China and India [1]. The increasing uses of automobiles causes air pollution because discharge of particulates, or biological materials into the atomosphere, causing discomfort, disease, or death to humans, and damage to living organisms [2]. The disposal of solid or liquid or gaseous waste materials in open land or underground can contaminate the soil or ground water, threaten public health, and cause land pollution. Water pollution occurs when pollutants or waste disposals are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds.The result of this causes global warming, ozone depletion, human health problems, death of forests, and infertility of the soil [3]. Alternative fuel technology, availability will more common in coming decades. In this point of view, waste transformer oil (WTO) can be an alternative source for petroleum oils. In India, there is a huge amount of transformer oil is rejected every year.WTO has similar physic-chemical properties. Transformer oil is used mainly in electrical transformer for insulation purpose. At present 100 percent transformer oil is not used in place of diesel fuel [DF] to run engine rather blends of WTO and DF are used to run the engine. Transformer oils are an important class of insulating oils. They act as a heat transfer medium in the transformer [4]. After certain period of time of operation in the transformer, the oil is thrown out of waste. But after testing transformer oil blends (transformer oil and diesel fuel) it has been seen that property of transformer oil is comparable to that of diesel [5]. The current study investigated the possibility of using WTO as a diesel substitute.

2. WASTE TRANSFORMER OIL (WTO):

The electrical transformer is an essential piece of equipment used in the transmission and distribution of the electrical energy that is installed in small, medium and large electrical distributing stations. It is also used in arc welding equipment and the electromotive units in trains. The performance and the life of an electrical transformer depend on the effective insulation and cooling.

Fig1: pure transformer oil

Table1: Comparison of the transformer oil with different base oils –

Name	Pour Point (°C)	Flash Point (°C)	Viscosity (cst) at 40 °C	Density (kg/m^3)
Mineral Oil	-50	147	9.2	800
Sunflower oil	-15	73	58.50[a]	918
Soya oil	-12.2	254	68.40[a]	914
Coconut oil	-40	234	50.1	912
Palm oil	-31.7	267	39.6	918

2.1 Degradation of transformer oil:

The transformer oil will deteriorate rapidly at high temperatures and moisture acts as a catalyst for its aging. There are also other substances and metals present in a transformer that are responsible for oil degradation. These include copper, paint, varnish and oxygen. The principal mechanism of transformer oil aging is oxidation which results in acids and other polar compounds being formed. When transformer oil is subjected to thermal and electrical stresses in an oxidizing atmosphere, it gradually loses its stability and becomes decomposed and oxidized, its acidity increases, and finally, it begins to produce mud [6].

Fig2: Photograph of the WTO sample after procuring

2.2 Filtering of the waste transformer oil:

Figure3 shows the schematic of the steps involved in the disposal of the WTO from transformer oil. Once the life of the oil was determined, the transformer oil was removed from the transformer and sent to settling.

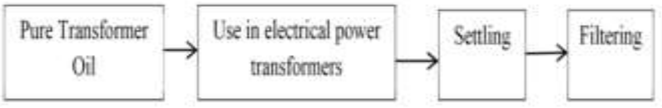

Fig 3: Disposal of the WTO from transformer

Now the disposed transformer oil has been categorized as WTO, a further two processes are involved in processing the oil (a) settling and (b) filtering. The processes are discussed below;
(a) Settling: Foreign particles and sediments of the WTO settle at the bottom of the oil tank. The settling works better in warm conditions and over a number of days or weeks. The settled WTO was drained from the oil tank.
(b) Filtering: Fine filters may be required depending on the application. For this study the WTO was filtered with the help of a fabric filter of size 30 microns.

3. EXPERIMENTAL SETUP & PROCEDURE OF EXPERMENTATION:

3.1 Mateials and methods:

The engine used in this experiment was a single cylinder, water cooled, 4-stroke, diesel engine. The engine specifications as shown in table 3. The experiment was conducted with conventional DF (Diesel Fuel) and different blends of WTO. The engine speed was measured directly from the tachometer attached with the dynamometer. The outlet of temperatures of cooling water and exhaust gases were directly from the thermocouples attached to the corresponding passages. The engine speed was fixed at constant at 1500rpm. An inclined water tube manometer, connected to the air box was used to measure the air pressure. Fuel consumption was measured by a burette attached to the engine. A stopwatch was used to measure fuel consumption time for every 50 ml of fuel. To investigate the suitability of DF three blends were prepared. All percentages were volumetric percentages. The blends are WTO10 (WTO10% and DF90%), WTO20 (WTO 20% and DF 80%), WTO30 (WTO 30% and DF70%). The brake power (BP), BSFC, and brake thermal efficiency were calculated by equations 1, 2 and 3 respectively.

BP = 2πNWR/60000 (Kw) ....(1)

Where, W is load in kg and N is engine speed in rpm.

BSFC= m_f /BP (kg/kWhr) .....(2)

Where, m_f is the mass flow rate of fuel in kg/hr.

Brake thermal efficiency= BP/m_f × CV (%)........(3)

Where, CV is the calorific value of fuel in KJ/kg.

Table2: Engine technical specifications-

Engine speed	1500rpm
BHP	5
Bore	87.5mm
Stroke	110mm
No. of cylinder	1
Dynamometer	Mechanical loading
Drum diameter	330mm
C_d (Coefficient of discharge)	0.65

Table 3: Fuel properties of DF and WTO-

SR NO.	PROPERTIES	DF	WTO
1	Density (Kg/m^3)	860	895
2	Kinematic viscosity (cSt)	3.08	10.01
3	Flash point (^{O}C)	90	140
4	Fire point (^{O}C)	95	145
5	Gross calorific value (KJ/kg)	44500	41175
6	Cetane number	48	42

Table 4: Properties of test fuels-

SR No.	Fuel	Fuel blend ratio (% vol)	Density Kg/m^3	Viscosity cSt @27^{O}C	Calorific value KJ/kg
1	Diesel	0/100	860	3.4	44800
2	WTO 10	10/100	835.3	3.4	43626.45
3	WTO 20	20/100	841	3.76	43584.58
4	WTO 30	30/100	847.4	4.03	43542.72

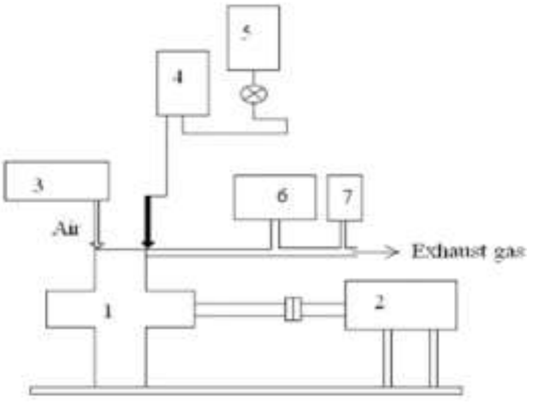

Fig 4: Engine specification

1.Engine 2. Dynamometer 3.Air plenum 4.U-tube
Manometer 5.Dual tank6.Exhaust gas analyzer.7.Smoke meter

Fig5: Single cylinder four stroke engine

3.2 Group compounds of DF and WTO:

The target of the current investigation to explore the alternative fuel for CI engine. FTIR (Fourier transform infrared spectra) analysis of WTO was performed as FTIR gives an idea about the suitability of WTO as DF. FTIR gives idea of the WTO to identify basic compositional groups. It provides the absorption spectrum in percentage incident intensity, along the wave numbers 4000 to 500 cm.

Table 5: FTIR analysis of diesel fuel-

Neat DF		
Frequency range (cm^{-1})	**Bond types**	**Family**
2923.9-2854.5	C-H streching	Alkanes
1458.3	C-H bending	Alkanes
1377.1	C-X	Flouride
723.3	=C-H bend	Alkanes

Table 6: FTIR analysis of WTO-

Neat WTO		
Frequency range (cm^{-1})	**Bond types**	**Family**
2963-2852.7	C-H streching	Alkanes
1456.2	C-H bending	Alkanes
1377.17	C-X	Flouride
730.2	C-H out of plane bend	Alkanes

The table 5 and 6 represents the functional group, compositional analysis for the DF and WTO. For DF, the strong absorbance frequencies 2923.9 and 2854.5 cm^{-1} represents C-H stretching. The absorbance peaks 1458.1 cm^{-1} represented the C-H bending which indicates the presence of alkanes. Based on above discussion it is clear that both of the oil is saturated hydrocarbon. The presence of hydrocarbon groups C-H indicates that the liquid has a potential to be used as a fuels [7].

4. RESULT AND DISCUSSION:

4.1 BP V/S BTE:

The variation of brake thermal efficiency with brake power using all types of fuels/ blends is as shown in figure 6. From the figure it is observed that brake thermal efficiency increases with increase in brake power for all fuels/blends. It is interesting to note that compared to DF, all WTO blends shows higher brake thermal efficiency. The maximum value of brake thermal efficiencies with WTO10, WTO20, WTO30 with DF blends were found to be 56.79%, 61.61%, 63.96% and 54.23% respectively. Because of the changes in the composition, viscosity, density and calorific value of WTO-DF blends [8].

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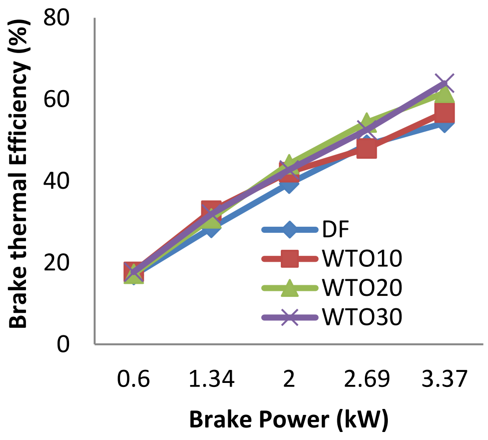

Fig 6: Variation of brake thermal efficiency with brake power for DF and WTO blends.

4.2 BP V/S BSFC:

Figure 7 show BSFC with different fuels/blends. It can be seen from the figure that the BSFC decreases with increase in brake power. It is interesting to note that the BSFC is lower with all WTO blends relative to DF [5].

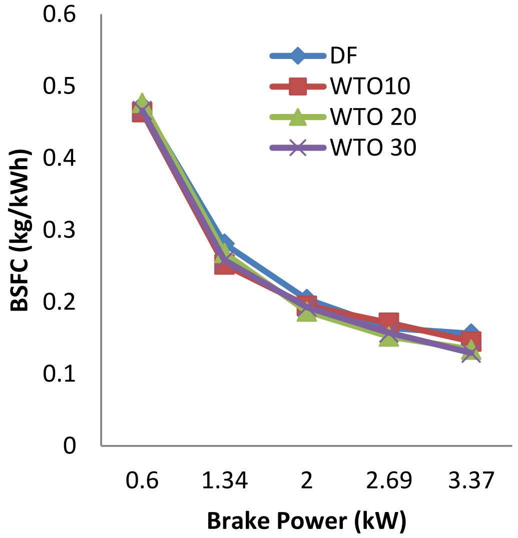

Fig 7: Variation of BSFC with brake power for DF and WTO blends.

4.3 Engine Torque V/S Fuel consumption:

Figure 8 show fuel consumption with different fuels/blends. It can be seen from the figure that the fuel consumption increases with increase in engine torque and there is slight curvature at light loads. It is interesting to note that the fuel consumption is higher with all WTO blends relative to DF. It is due to difficulty in injecting accurately & consistently very small quantities of fuel per cycle [9].

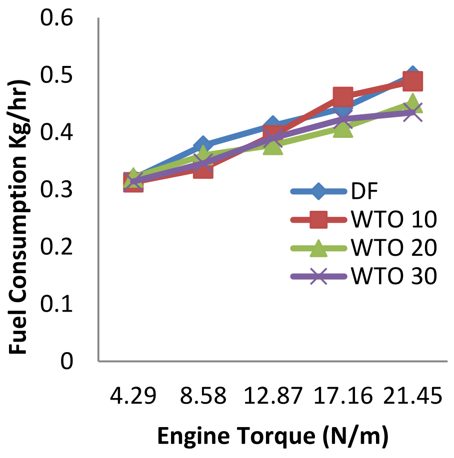

Fig 8: Variation of fuel consumption with engine torque for DF and WTO blends.

4.4 BP V/S Exhaust gas temperature:

The variation of exhaust gas temperature at various brake power as shown in figure 9. It is observed that exhaust gas temperature increases with BP because more fuel is burnt to meet the power requirement. Higher exhaust gas temperature in case of WTO blends compared to DF due to higher heat release rate. It may be due to oxygen content of WTO which improve combustion.

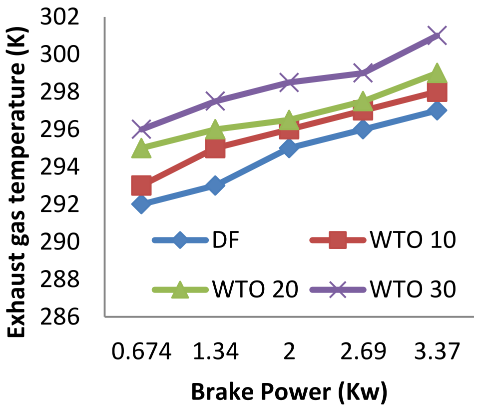

Fig 9: Variation of exhaust gas temperatures with brake power for DF and WTO blends.

4.5 Mean effective pressure V/S fuel consumption:

The variation of fuel consumption with mean effective pressure as shown in figure 10. The fuel consumption increases with increase in mean effective pressure. Higher fuel consumption for WTO blends compare to DF due to proper combustion.

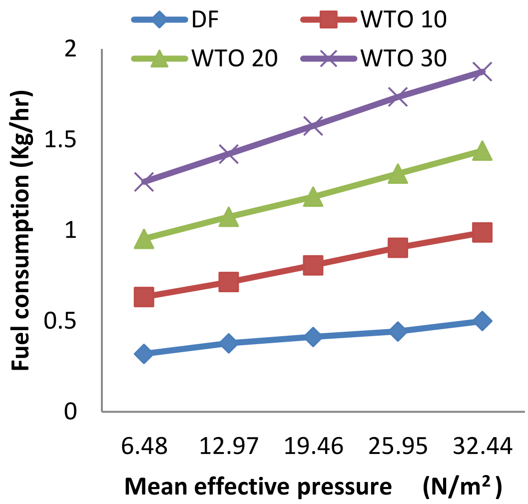

Fig 10: Variation of fuel consumption with mean effective pressure for DF and WTO blends

5. CONCLUSION

[1] WTO can be used as a fuel in CI engine as it possesses a heating value.
[2] The brake thermal efficiency for each blend was found to be high because of proper combustion. The brake thermal efficiency for WTO10, WTO20, WTO30 was found to be 56.79%, 61.61%, 63.96% where diesel was 54.23% for the same power output.
[3] The BSFC decreased with blends of WTO compared to DF due to lower heating value. Considering BSFC WTO30 can be the optimum blend.
[4] The exhaust gas temperature of WTO10, WTO20, WTO30 were 25^{o}C, 26^{o}C, 28^{o}C respectively which were higher than diesel 24^{o}C due to more residence time and higher viscosity.

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