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Effect of Used Transformer Oil on Efficiency of Compression Ignition Engine

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***Abstract* - Price hike in petroleum and limited availability of petroleum resources leads to the researchers now a days to look for alternate fuels products. Several types of biological materials, chemical agents and petroleum blends have been investigated by numerous scientists around the world during last decades. Many of them have also investigated the waste materials like waste vegetable oils, waste cooking oils etc. Used transformer oil (UTO) is also a waste product which is used for cooling purpose and after its application it is thrown out in the form of waste. After testing the waste/used transformer oil, it has been seen that it has high ignition temperature and high viscosity with high energy density. Blending of transformer oil with conventional diesel fuel reduces its viscosity and improves its ignition quality which makes it to be used in diesel engines. In present work blends of UTO (UTO50%, UTO20% on volume basis) is used in AVI model, Kirloskar make constant speed, four stroke, Single cylinder, water cooled, direct injection compression ignition engine. Initially the engine was operated with neat diesel and the performance, and combustion parameters were evaluated. The engine was allowed to run with UTO50 and UTO20 respectively and the performance and combustion parameters were evaluated. It was seen that the brake thermal efficiency UTO50 is 32.01% and that of diesel is 28.64%. The specific energy consumption of UTO50 is found to be 11.2443MJ/kW-hr. The diesel showed the maximum energy consumption at all the loads. The exhaust gas temperature of UTO50 at full load is 325°C and that of diesel is 269.54°C. The peak pressure for UTO50 increased from 53 bars from zero loads to 72 at full load. The peak pressure for diesel is increased from 55 bars from zero loads to 74 at full load.**

***Keywords* – Transformer Oil, Blending of Fuels, Specific fuel consumption, Brake thermal efficiency**

1. INTRODUCTION

Transformer oil or insulating oil is usually a highly-refined mineral oil that is stable at high temperatures and has excellent electrical insulating properties. It is used in oil-filled transformers, some types of high voltage capacitors, fluorescent lamp ballasts, and some types of high voltage switches and circuit breakers. Its functions are to insulate, suppress corona and arcing, and to serve as a coolant. The oil helps in cooling the transformer. Transformer oils are produced from wax-free naphthenic oils. Although these types of crudes permit production of exceptionally low pour point insulating oils, they also contain high percentages of Sulphur and Nitrogen which must be removed in order to satisfy the stringent stability requirements of insulating oils [Reid and Gudelis, 1977]. After prolonged use, the transformer oil becomes deteoriated and becomes waste. However, the waste or used transformer oil (UTO) posses a considerable heating value and some of the properties similar to that of diesel fuel [Behera and Murugan, 2013]. Therefore, it can be used as an alternative fuel in compression ignition engines. The principal measure of diesel fuel quality is its cetane number. A higher cetane number indicates that the fuel ignites more readily when sprayed into hot compressed air. European (EN 590 standard) road diesel has a minimum cetane number of 51 [Oluwafunmilayo et al, 2012]. Chemical name of used transformer oil is Severely Hydro treated Heavy Naphthenic Distillate [Behera and Murugan, 2013]. Some of the physical properties of transformer oil and diesel fuels are listed in the table 1.

Table 1: Physical properties of transformer oil and diesel fuel

PROPERTY	UTO	UTO50	PURE DIESEL
Sp. Gravity at, 27 °C	0.830	0.866	0.820
Kinematic Viscosity, cst at 27°C	13	7.3	3.292
Gross Calorific Value KJ/kg	39120	41928	42,640

Flash Point, °C	150	90	69
Fire Point, °C	172	102.4	79
Auto ignition point, °C	204	-	256
Sulphur Content, %	0.020	0.035	-
Ash Content, %	-	.006	-
Carbon Residue, %	0.020	0.029	-

Legends: UTO: Used Transformer Oil, UTO50: 50%Used Transformer Oil+ 50%Diesel fuel.

Diesel combustion, which is in principle unsteady turbulent diffusion combustion, is fundamentally controlled by the mixing process of fuel with air in the combustion chamber. Since the air temperature and pressure are above the fuel's ignition point, spontaneous ignition of portions of the already-mixed fuel and air occur after a delay period of few crank angle degrees [Heywood, 1988]. The combustion process is shown in the figure 1.

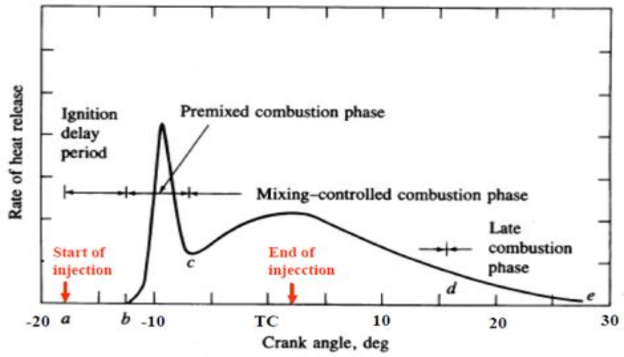

Figure 1: Rate of heat release Curve for Diesel Engine [4]

2. LITERATURE REVIEW

Numerous research papers around the world have been appeared in various conferences and journals, which promote the use of alternate fuels in the internal combustion engines. Blends of diesel with different chemical agents, biodiesel, vegetables oil and waste oils from industries and houses have been tested by several researchers during the recent time, which proposed the several alternatives fuels for diesel engines. Used transformer oil is also a waste product. Its energy density capacity makes it to be used as a fuel. Stumborg, (1989) studied alternative fuel parameters for a diesel engine. The study [Stumborg, 1989] was done to evaluate the parameters of direct injection, turbocharged, diesel engine that would give the allowable substitution for diesel fuel. Bihari, B., (1998) observed that the power producing capabilities, reduced bsfc, increased thermal efficiency of the diesel blends prepared were comparable to diesel fuel. Ajav et al, (2000) conducted a study to establish thermal balance of a constant speed, medium size, single cylinder, compression-ignition engine operating on ethanol-diesel blends and fumigated ethanol. The purpose was to determine the thermal balance of the engine at different loading conditions. P.Behera, S.Murugan, (2011) proposed the use of UTO and its different blends in CI engines because of its shorter ignition delay period than diesel fuel. Gandhi et al, (2012) used the blend of UTO with 40% and 60% diesel respectively and found the emission of the fuel within the acceptable limits. Behera and Murugan, (2013) experimentally investigated the Engine performance; emissions were measured and compared to that of diesel fuel. From the analysis it was found that brake thermal efficiency and nitric oxide (NO) emissions of UTO and its blends increases while smoke decreases compared to that of diesel.

Literature reveals that various approaches to find an alternate fuel for diesel engines have been reported. These approaches differ strongly from each other with respect to the fuel preparation and tested methods.

3. EXPERIMENTAL SETUP

The engine used for the present investigation is AVI model, Kirloskar make constant speed, four stroke, Single cylinder, water cooled, direct injection compression ignition engine. The test set up consists of the engine coupled to a rope brake dynamometer along with controller. The experimental set-up also consisted of a SAJ-froude make, SFV-75 model electronic volumetric fuel consumption measuring unit. The specifications of the engine are shown in table below:

Table 2: Description of Experimental Set up

Make	Kirloskar
Model	AVI Stationary engine
Rated Brake power (bhp/KW)	5/3.73
Number of cylinders	One
Bore × Stroke (mm× mm)	80×110
Displacement volume (cc)	552.920
Compression Ratio	16.5:1
Standard injection timing	27^0 BTDC
Cooling System	Water cooled

Legends: AVI: Activity Value Index, BTDC: Before Top Dead Centre, CC: Cubic Centimetre

The pictorial representation of the experimental set up is shown in the following figure.

Figure 2 Pictorial diagram of experimental setup

3.1 TEST PROCEDURE

The following procedure is adopted for calculating the Brake specific fuel consumption and brake thermal efficiency of C.I engine using used transformer oil and blend of used transformer oil.

- The Rope Brake Dynamometer is coupled with the required prime mover, properly on a suitable bed.
- Fix the hanger (with a dead weight) to the hook. (Once this hanger is fixed, it need not to be removed, it can stay there permanent.)
- Adjust the hand wheel above the balance, so that the pointer reads zero on the balance.
- Now, start the prime mover and bring to its normal speed.
- Open the gates slowly, by rotating the hand wheel 'OPEN' direction. There is a lock on the top gearwheel.
- Take the reading in the balance.
- Measure the speed of the rotation.
- The B.P.= $2\pi(N/60)\ \{9.81x(s_1\text{-}s_2)\}R_{eff}$ / 1000 KW
  Where S_1= spring balance reading (kg)
  S_2= spring balance reading (kg)
  R_{eff}= effective radius of brake drum
  = (D+d)/2
  D= brake drum dia.
  d= rope dia.

N=R.P.M.

- If the balance reading exceeds 20kg then the additional dead weight of 10kg is placed on the Hanger. The balance reading is added with 10kg to find the total weight.
- BSFC = (mass of the fuel consumption per unit time / B.P.)
- Brake Thermal efficiency (η_{th}) = (Brake Power) / (Mass of fuel x Calorific Value of fuel).

4 RESULTS AND DISCUSSION

Performance test are carried out on the compression ignition engine, using UTO and blends of UTO with diesel as fuels. The tests are conducted at the rated speed of 1500 rpm at various loads. The experimental data generated are documented and presented here using appropriate graphs. These tests are aimed at optimizing the concentration of ester to be used in the biodiesel-diesel mixture for long-term engine operation. In each experiment, engine parameters related to thermal performance of the engine such as fuel consumption and applied load are measured.

The variation of brake thermal efficiency with brake power is shown in Figure 3. The brake thermal efficiency UTO50 is 32.01% and that of diesel is 28.64%. UTO exhibits the brake thermal efficiency of 31.72% at full load.

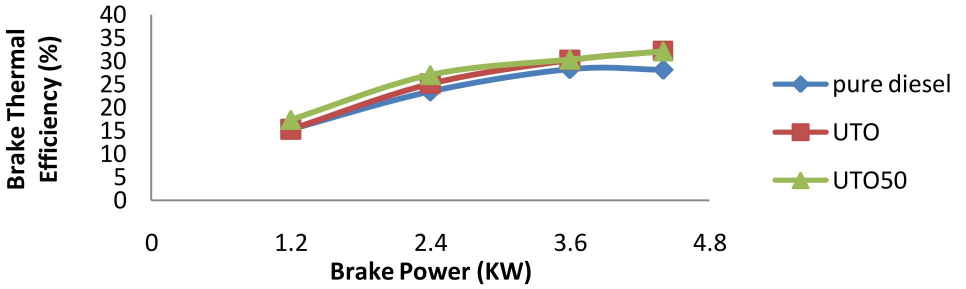

Figure 3 Variation of brake thermal efficiency with brake power

Figure 4 shows the variation of brake specific energy consumption with the brake power. The specific energy consumption of UTO50 is found to be 11.2443 MJ/kW-hr. The diesel shows the maximum energy consumption at all the loads.

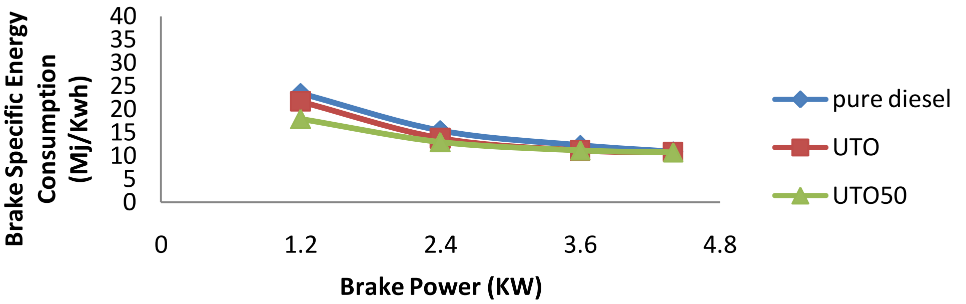

Figure 4 Variation of brake specific energy consumption with brake power

The variation of volumetric efficiency of fuels is shown in the Figure 5. The volumetric efficiency is calculated as the ratio of actual volume of air passed into the engine to the swept volume.UTO50 and UTO shows more volumetric efficiency. The diesel fuel possesses the volumetric efficiency of 12.81% at full load, intermediate of UTO50 and UTO.

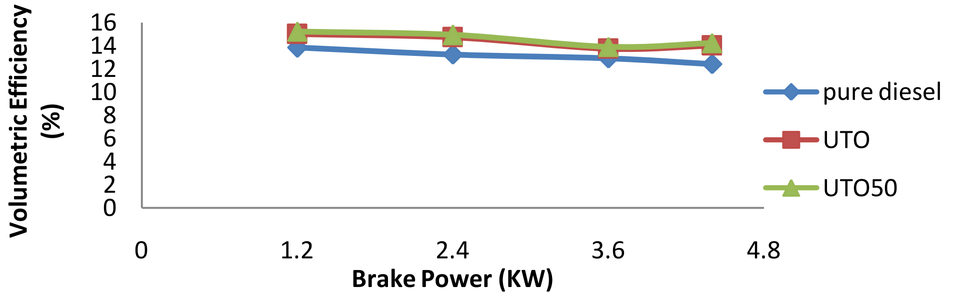

Figure 6 Variation of volumetric efficiency with brake power

5 CONCLUSIONS

The performance and combustion parameters of the engine using UTO50 and UTO as main fuels were obtained in the investigation are compared with the diesel fuel. The following conclusions are drawn:

1. UTO50 (50%UTO blend with 50% diesel fuel on volume basis) has shown better performance compared to all other blending proportion with diesel. Also with UTO, the engine was able to run.
2. The brake thermal efficiency UTO50 is 32.01% and that of diesel is 28.64%. UTO exhibits the brake thermal efficiency of 31.72% at full load.
3. The specific energy consumption of UTO50 is found to be 11.2443MJ/kW-hr. The diesel had shown the maximum energy consumption at all the loads.
4. UTO50 and UTO shown more volumetric efficiency. The diesel fuel possesses the volumetric efficiency of 12.81% at full load, intermediate of UTO50 and UTO.
5. The peak pressure for UTO increased from 56 bars from zero loads to 76 at full load. The peak pressure for UTO50 increased from 53 bars from zero loads to 72 at full load. The peak pressure for diesel is increased from 55 bars from zero loads to 74 at full load.

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