EXPERIMENTAL INVESTIGATION ON CI ENGINE USING WASTE TRANSFORMER OIL METHYL ESTERS AS BIO DIESEL

S.Kirankumar[1*]
[1]Department of Mechanical Engineering, Bulehora University, Oromia region, Ethiopia

ABSTRACT

Modernization and increase in the number of automobiles worldwide, the consumption of diesel and gasoline has enormously increased. Day by day the demand for non renewable energy sources increases. Automobile leads to demand for petroleum based fuels. The present investigation oil is taken the waste transformer oil .The transformer oil is produced from wax-free naphthenic oils. Transformer oils are an important class of insulating oils. They act as a heat transfer medium in the transformer. After certain period of time of operation in the transformer the oil is thrown out in the form of waste. So the suitability of using waste transformer oil as alternative fuel for compression ignition engine and comparing its performance parameters with conventional diesel. Experimental investigation is carried out on 4 strokes –twin cylinder water cooled diesel engine. Preparing blends of transformer oil with diesel like T10, T20, T30, and T40 and comparing its performance parameters with conventional diesel. Among these blends selecting optimum blend and adding ignition improver in a different proportions and finding optimum blend. Then comparing performance parameters of the optimum blend with conventional diesel fuel. Here use Isopropyl alcohol is as ignition improver for optimum blend. Based on the earlier finding the current experimental investigation investigated the possibility of using waste transformer oil is a diesel substitute. The objective of the present research was to explore technical feasibility of waste transformer oil in direct injection C.I engine without any substantial modifications in the engine design.

KEYWORDS: *Waster transformer oil; Biodiesel; Transesterification; Performance characteristics; Emission characteristics; Isopropyl alcohol*

1.0 INTRODUCTION

Decline in fossil fuel resources along with high crude oil prices generated attention toward the development of fuel from alternate sources (Demirbas, 2011), (Lin et al., 2011). Such fuel should be economically attractive and performance competent in order to replace the fossil fuel (Singh, Kaur & Singh,2010). Biodiesel has emerged as a clean fuel. Biodiesel offers a very promising alternative to diesel oil since they are renewable

*Corresponding author e-mail: kirankumar.sureddy@gmail.com

and have similar properties (Jaichandar & Annamalai, 2011). Vegetable oils may be edible or non edible. Use of non edible vegetable oils is recommended by Ministry of non-renewable energy (MNRE), India. Also, throughout the world, there is an enormous amount of waste lipids generated from restaurants and food shops posing a challenge for their storage and proper disposal in the environment. Reuse of these oils not only helps in its management but also lowers the production cost of biodiesel. Bio waste cooking oils thus opened a good opportunity to study its suitability to produce biodiesel. Waste mustard oil is easily available in abundance in Indian sub-continent and can be easily collected from any local restaurant (Hasib, Hossain, Biswas & Islam, 2011). Biodiesel can be fueled into a C.I engine up to a specified blending with the mineral diesel without changing the existing design of the engine cylinder (Singh, Kaur & Singh, 2010). The problem lies in the high viscosity of the bio waste cooking oils (Demirbas, 2011), (Rao, Sampath & Rajgopa, 2008). Transesterification process can be used as a handy tool to reduce the viscosity of the waste oil (Demirbas, 2011). Biodiesel can be prepared by mainly four methods i.e. transesterification, pyrolysis, micro-emulsion technique or can be used by direct blending (Sing & Sing, 2010). An experimental study was also carried out to examine fuel properties, performance and emissions of different blends of waste transformer oil in comparison to diesel fuel. Performance characteristics and ignition improver biodiesel fueled C.I engine were evaluated and compared with that by fueling diesel while the engine running at no, part and full load condition. The objectives of this experimental study are to assess performance and emission characteristics of a diesel engine when tested with selected fuels and compared with diesel as a reference fuel.

2.0 EXPERIMENTAL SET-UP AND PROCEDURE

2.1 Experimental Set Up

Experimental set up consists of a water cooled twin cylinder vertical diesel engine coupled to a rope pulley brake arrangement it shown in Figure 1, to absorb the power produced necessary weights and spring balances are induced to apply load suitable cooling water arrangement for the brake drum is provided. A fuel measuring system consists of a fuel tank mounted on a stand, burette and a three way cock. Air consumption is measured by using a mild steel tank which is fitted with an orifice and a U-tube water manometer that measures the pressures inside the tank. This is a water cooled twin cylinder vertical diesel engine is coupled to a rope pulley brake arrangement to absorb the power produced necessary weights and spring balances are induced to apply load on the brake drum suitable cooling water arrangement for the brake drum is provided. Separate cooling water lines are provided for measuring temperature. A fuel measuring system consists of a fuel tank mounted on a stand, burette and a three way cock. Air consumption is measured by using a mild steel tank which is fitted with a orifice and a U-tube water manometer that measures the pressures inside the tank. Also digital temperature indicator with selector switch for temperature measurement and a digital rpm indicator for speed measurement are provided on the panel board. A governor is provided to maintain the constant speed. For measuring the emissions the gas analyzer is connected to the exhaust flow.

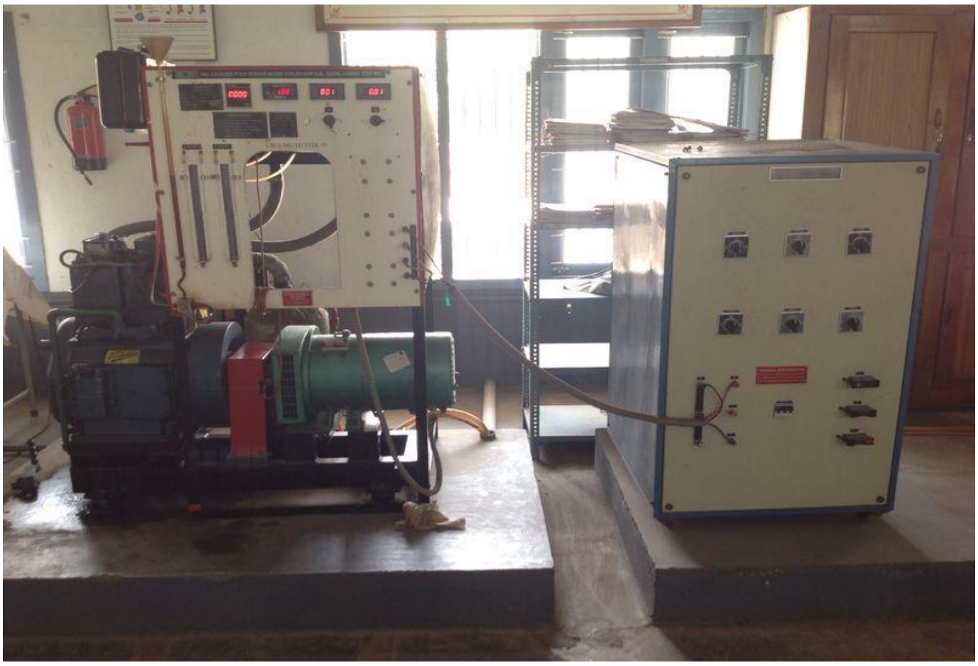

Figure 1. Four stroke twin cylinder water cooled diesel engine

2.2 Test Fuels

For experimental investigation Using TOME oil tests are to be conducting on different equipment's, to be found some of the fuel properties. Performance tests were conducted on 4- stroke twin cylinder water cooled diesel engine. The properties of test fuels are given in Table 2 compares the properties of neat diesel and blends with TOME oil.

Table 2. Properties of WTO and RWTO with Diesel

Properties	WTO	RWTO	DF
Density[kg/m^3]	895	874	830
Kinematic viscosity[cSt]	10.1	6.2	3.08
Flash point [^{O}C]	140	125	60
Fire point [^{O}C]	145	132	65
Gross calorific value[kJ/kg]	41775	43813	44500
Cetane number	42	50	48

2.3 Experimental Procedure

The experiments are conducted on the four stroke twin cylinder water cooled diesel engine at constant speed (1500 rpm) with varying 0 to 100% loads with diesel and different blends of TOME like T10, T20, T30, T40, T40%D59.5%IPA 5ml and T40%D59%IPA 10ml .The performance parameters such as brake thermal efficiency and brake specific fuel consumption were calculated from the observed parameters and shown in the graphs. The variation of performance parameters are discussed with respect to the load for diesel fuel, diesel-biodiesel blends and obtained optimum blend with adding ignition improver are discussed in below.

3.0 PERFORMANCE ANALYSIS

3.1 Performance Analysis Using Pure Diesel And Its Blends Of Tome

In this stage various performance parameters characteristics are discussed in below for diesel, TOME diesel blends.

3.1.1 Brake thermal efficiency

The brake thermal efficiency is calculated by the ratio of brake power to the input power. From the observations and graph between brake thermal efficiency and load that the brake thermal efficiency is increases with the increase in engine load for all fuels /blends. When compared to diesel fuel all RWTO blends show higher brake thermal efficiency. The variation of brake thermal efficiency with load for different fuels. In all cases, it increased with increase with increase in load. This was due to reduction in heat loss and increase in power with increase in load. The maximum thermal efficiency for T40 at full load 41.6% was higher than that of diesel (40.12%). Increase in thermal efficiency due to % of oxygen presence in the biodiesel, the extra oxygen leads to causes better combustion inside the combustion chamber. The thermal efficiency of the engine is improved by increasing the concentration of the biodiesel in the blends and also the additional lubricity provided by biodiesel. The reason may be the leaner combustion of diesel and extended ignition delay resulting in a large amount of fuel burned. The graph between load and brake thermal efficiency is shown in fig 3.1

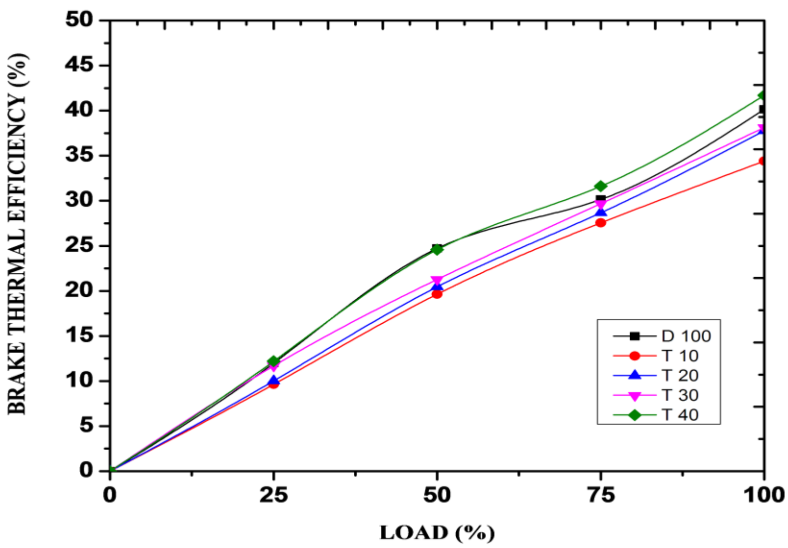

Figure 2. Variation of brake thermal efficiency with load using TOME blends & diesel

3.1.2 Mechanical Efficiency

It is the ratio of brake power to the indicated power .it may observe that mechanical efficiency is always less than unity. The comparison of Mechanical efficiency for various biodiesel blends with respect to brake power. From the plot it is observed diesel and its blends like T40 nearly equal at full load conditions. But considerable improvement in mechanical efficiency was observed by the blend T40 is72.54 % because of lowest frictional powers compared to diesel. Because of sufficient lubricating property of this blend frictional powers are reduced drastically and considerable improvement in mechanical efficiency has been observed and calorific value of this blend is more compared to other blends. The graph between load and mechanical efficiency is shown in Figure 3.

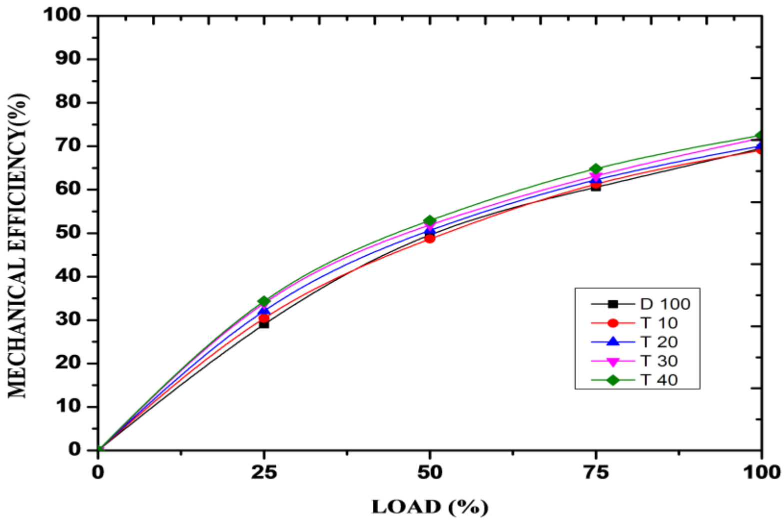

Figure 3. Variation of mechanical efficiency with load using TOME blends and diesel

3.1.3 Brake Specific Fuel Consumption

How efficiently an engine using the working supplied fuel to power is known as brake specific fuel consumption. From the graphs we can observe BSFC decreases with the increase in load. Brake-specific fuel consumption (BSFC) is the ratio between mass fuel consumption and brake effective power, and for a given fuel, it is inversely proportional to thermal efficiency. BSFC decreased sharply with increase in brake power for all fuels. The main reason for this could be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power, because relatively less portion of the heat is lost at higher load. It can be observed that the BSFC of 0.2016 kg/kw-hr were obtained for diesel and 0.200381 kg/kw-hr T40 at full load. It was observed that BSFC decreased with the increase in concentration of TOME in diesel. The BSFC of Bio-diesel is decreases up to 2.8% as compared with diesel at full load condition. The graph between load and Brake specific fuel consumption efficiency is shown in Figure 4.

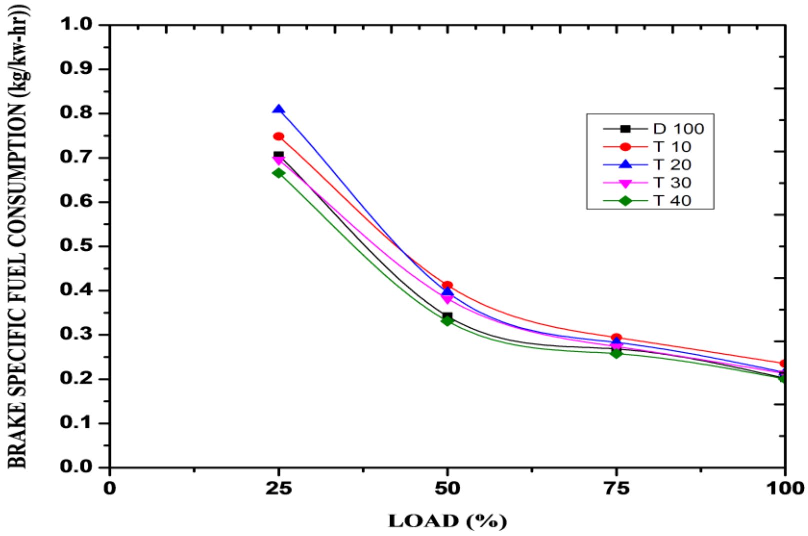

Figure 4. Variation of BSFC with Load using TOME blends and diesel

3.1.4 Indicated Specific Fuel Consumption

The variation of Indicated Specific Fuel Consumption with load. It is observed that from the graphs T40 line varies similar with the diesel. At full load ISFC of diesel is 0.140 kg/kW-hr and for T40 are 0.14537 kg/kW-hr. This improvement in ISFC was perhaps due to better combustion of the fuel, which may be attributed to the presence of oxygen in the blend. Esterification also helps to lower the temperature reaction and better combustion.

3.1.5 Volumetric Efficiency

It is the ratio of actual volume to rate of swept volume. The graph between load and volumetric efficiency is shown in Figure 5. The actual volume of air which is inducted for the combustion of TOME is less with respect to stoichiometric A/F ratio and therefore the volumetric efficiency of the engine is slightly decreased when TOME is used as fuel. It has been observed that there is slight change in volumetric efficiency with the increase in Brake power in TOME blends and diesel at all loads. The value of volumetric efficiency is at full load condition for T40 is 83.82% for diesel it is 83.81%.

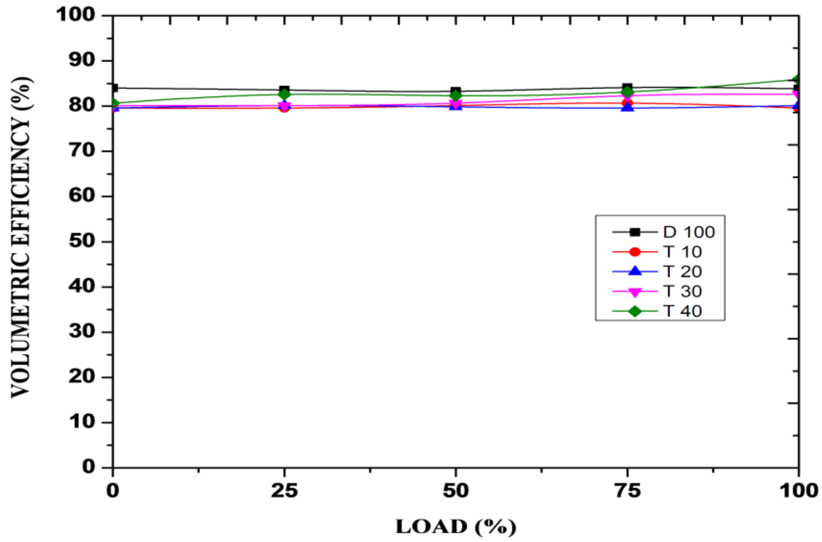

Figure 5. Variation of volumetric efficiency with load using TOME blends and diesel

3.1.6 Air-Fuel Ratio

The A/F ratio that was obtained from calculations is plotted against load and compared the results for different blends of fuels. As the percentage of TOME is increased in blends A/F ratio increased negligibly for T10, T20 T30 T40 blends at constant injection pressure. A/F for diesel is 49.75%; where as in case of T40 is 48.72%. The air fuel ratio decreases due to increase in load because of the compensation of load can only be done with increasing the quantity of fuel injection to develop the power required to bare load. The graph between load and Air fuel ratio is shown in Figure 6.

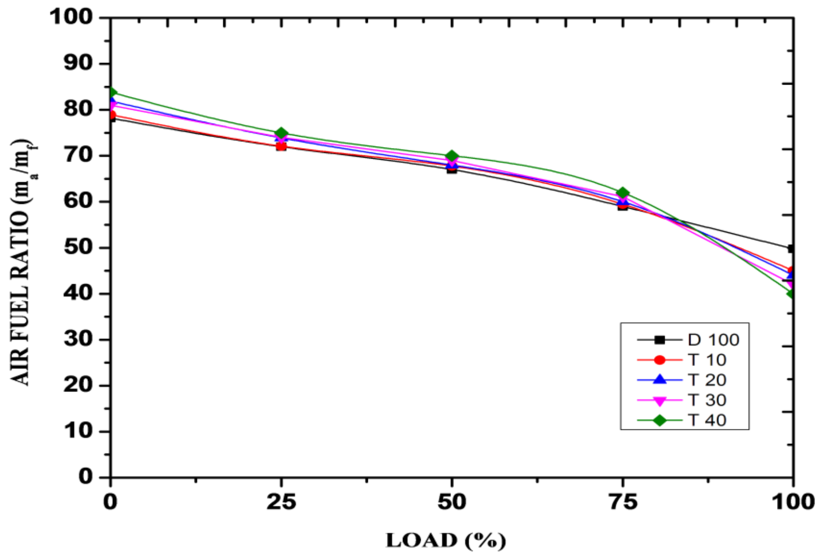

Figure 6 Variation of Air fuel ratio with Load using TOME blends and Diesel

3.2 Performance Analysis Using Diesel And Optimum Blend With Ignition Improver Using 5ml And 10ml

The present work preferred to use Isopropyl Alcohol as ignition improver .The chemical formula of Isopropyl Alcohol is C_3H_8O or C_3H_7OH. Isopropyl alcohol is a colorless, flammable, and strong chemical compound. It is miscible in water, alcohol.

3.2.1 Brake Thermal Efficiency

The brake thermal efficiency increases with increase ignition improver by volume percentage in blends. From all the above results blend with added ignition improver. The brake thermal efficiency at full load condition for diesel it is 40.12% while for blend T40D59.5IPA5ml it is 41.739% and blend T40D59IPA10ml it is 43.776%. The graph between load and brake thermal efficiency is show in Figure 7.

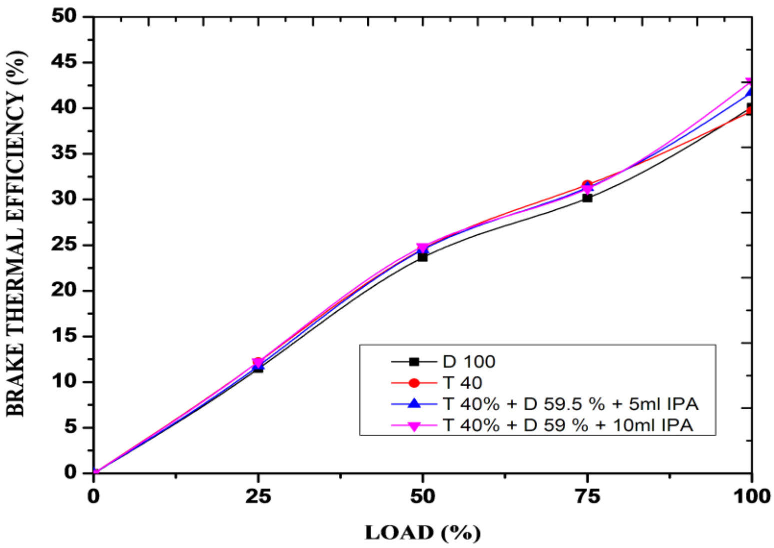

Figure 7. Variation of Brake Thermal Efficiency with Load using optimum blend T40 with ignition improver Isopropyl alcohol

3.2.2 Mechanical efficiency

Mechanical efficiency for Diesel fuel is 69.51% and T40D59.5IPA5ml it is 73.1%. And T40D59IPA10ml it is 73.649%. The maximum brake thermal efficiency is obtained by blend T40D59IPA10ml. The graph between load and Mechanical efficiency is show in Figure 8.

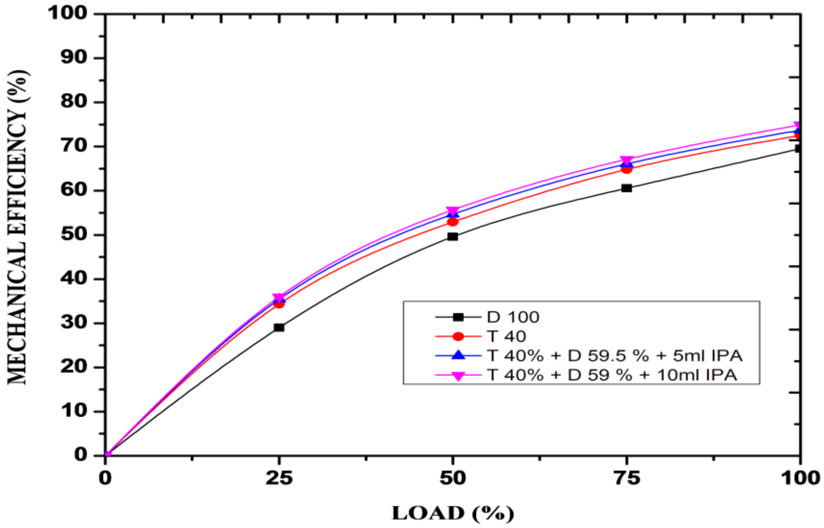

Figure 8. Variation of Mechanical Efficiency with Load using optimum blend T40 with ignition improver Isopropyl alcohol

3.3.3 Brake Specific Fuel Consumption

Brake specific fuel consumption for diesel is 0.201 kg/kw-hr mean while for blend T40D59.5IPA5ml it is 0.1950 kg/kw-hr and blend T40D59 IPA10ml is 0.1911 kg/kw-hr.The graph between load and Brake specific fuel consumption is show in Figure 9.

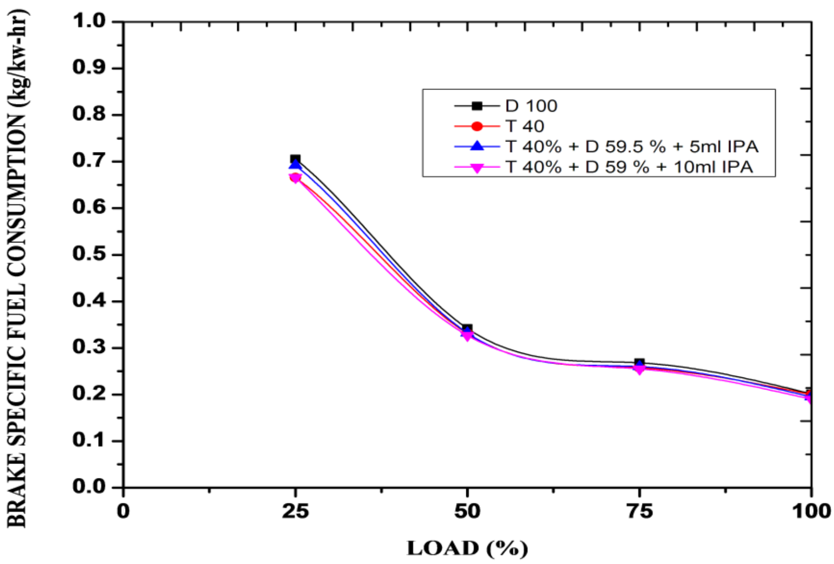

Figure 9. Variation of Brake specific fuel consumption with Load using optimum blend T40 with ignition improver Isopropyl alcohol

3.3.4 Volumetric Efficiency

It is the ratio of actual volume to rate of swept volume. The graph between load and volumetric efficiency is shown in Figure 10. It has been observed that there is slight change in volumetric efficiency with adding Isopropyl Alcohol to the optimum T40 blend at all loads. The value of volumetric efficiency is at full load condition for T40 is 83.82% for diesel it is 83.81%. Mean while volumetric efficiency for blend T40D59.5IPA5ml is 83.83%. Mean while the Blend T40D59IPA10ml it is 83.89%.

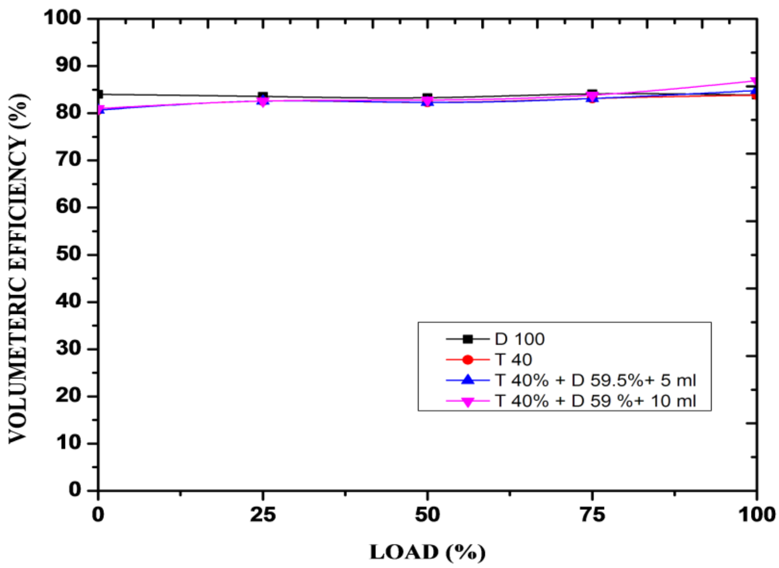

Figure 10. Variation of Volumetric efficiency with Load using optimum blend T40 with ignition improver Isopropyl alcohol

3.3.5 Air fuel ratio

It has been observed that there is slight change in air fuel ratio with adding Isopropyl Alcohol to the optimum T40 blend at all loads. The value of air fuel ratio is at full load condition for T40 is 48.72 for diesel it is 49.75. Mean while volumetric efficiency for blend T40D59.5IPA5ml is 48.7 and Blend T40D59IPA10ml it is 48.67. The graph between load and air fuel ratio is shown in Figure 11.

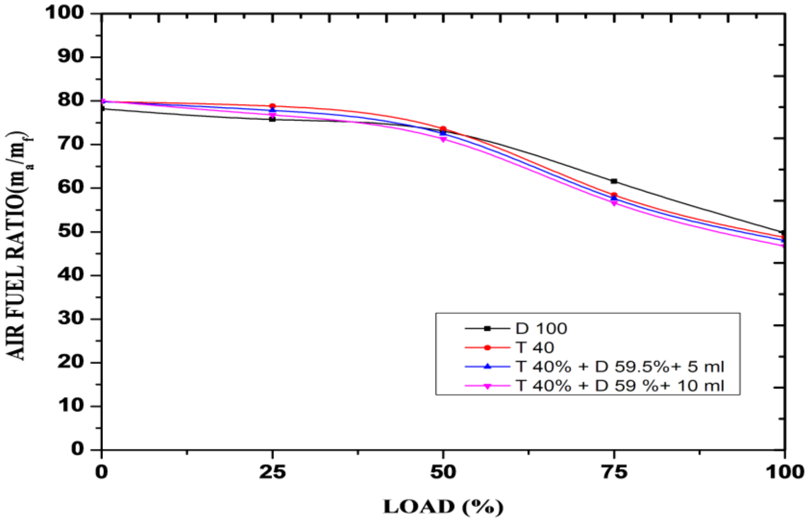

Figure 11. Variation of air fuel ratio with load using optimum blend T40 with ignition improver isopropyl alcohol

4.0 CONCLUSIONS

The main objective of this experiment is to use waste transformer oil as an alternative fuel for compression ignition engine. The pure diesel was used as base fuel for comparing properties and performance parameters. The brake thermal efficiency increases with increase bio diesel percentage. The brake thermal efficiency for each blend was found to be high because of proper combustion. The brake thermal efficiency for T10, T20, T30, T40 were found to be 34.41%, 37.75%, 38.13%, 41.63%. Out of all the blends T40 shows best performance parameters when compared to diesel. The maximum brake thermal efficiency obtained is 41.63% with T40 blend. The brake specific fuel consumption for T10, T20, T30, T40 were found to be0.2354 kg/kw-hr,0.21490 kg/kw-hr,.0.21315 kg/kw-hr, 0.2003 kg/kw-hr .out of all the blends T40 having low specific fuel consumption when compared to diesel fuel. Since T40 blend reduces the environmental pollution, high in thermal efficiency when compared with diesel it will be a promising renewable energy source for sustaining the energy.

In further stage the investigations were carried out on the 4 stroke twin cylinder water cooled Diesel engine with addition of Isopropyl Alcohol (ignition improver) 5%, 10% volume ratios to optimum blend T40 (T40D59.5IPA5, T40D59IPA10) find out performance parameters and compared with optimum blend and Diesel base line data. Out of this 10% volume addition of ignition improver (T40D59IPA10) shows best and give high brake thermal efficiency and low specific fuel consumption at full load conditions. The conclusions of this investigation are compared with optimum blend T40 and Diesel base line data at full load as follows:The brake thermal efficiency increases with increase ignition improver by volume percentages in blends.The brake thermal efficiency at full load condition for Diesel it is 40.12% while for blend T40D59.5IPA5ml it is 41.739% and for blend T40D59IPA10ml it is 43.776%. Mechanical efficiency for Diesel fuel is 69.51% and for T40D59.5IPA5ml it is 73.1%

and for T40D59IPA10ml it is 73.649%.The maximum mechanical efficiency is obtained by T40D59IPA10ml. Brake specific fuel consumption for Diesel is 0.201 kg/kw-hr meanwhile for blend T40D59.5IPA5ml it is 0.1950 kg/kw-hr & blend T40D59.5IPA10ml it is 0.1911 kg/kwhr. The value of volumetric efficiency is at full load condition for T40 is 83.82% for diesel is 83.81%mean while volumetric efficiency for blend T40D59.5IPA5ml is 83.83%. Mean while the Blend T40D59IPA10ml it is 83.89%.The value of air fuel ratio is at full load condition for T40 is 48.72 for diesel it is 49.75. Mean while air fuel ratio for blend T40D59.5IPA5ml is 48.7 and blend T40D59IPA10ml it is 48.67.

From all these discussion it can be concluded that Diesel engine can perform satisfactorily on bio-Diesel blends T40 with addition of ignition improver with 10ml without any engine design modification.

REFERENCES

Banapurmatha, N. R., Tewaria, P.G. & Hosmath, R.S. (2008). Performance and emission characteristics of a DI compression ignition engine operated on honge, jatropha and sesame oil methyl esters, *Renewable Energy*, *33*, 1982-1988.

Bannikov, M.G. (2011), Combustion and Emission Characteristics of mustard biodiesel, *6th International Advanced Technologies Symposium (IAST'11), Turkey*, 1-15.

Demirbas, A. (2011). Progress and recent trends in biodiesel fuels , *Progress in Energy and Combustion Science, 50*, 14-34.

Hasib, Z. M., Hossain, J., Biswas, S. & Islam, A. (2011). Biodiesel from Mustard oil: A renewable alternative fuel for small diesel engines, *Modern Mechanical Engineering*, *1*, 77-83.

Hoekman, S.K. & Robbins, C. (2012). Review of the effects of biodiesel on NOx emissions, *Fuel Processing Technology, 96*, 237-249.

Jaichandar, S. & Annamalai, K. (2011). The status of biodiesel as an alternative fuel for diesel engines, *Journal of Sustainable Energy and Environment*, *2*, 71-75.

Lapuerta, M.A.O & Rodriguez-Fernandez, J. (2008). Effect of biodiesel fuels on diesel engine emissions, *Progress in Energy and Combustion Science, 34,* 198-223.

Lin, L., Cunshan, Z., Vittayapadung, S., Xiangqian, S. & Mingdong, D. (2011). Opportunities and challenges for biodiesel fuel, *Applied Energy, 88*, 1020-1031

Lujan, J. M., Bermudez, V., Tormos, B. & Pla, B. (2009). Comparative analysis of a DI diesel engine fuelled with biodiesel blends during the European MVEG-A cycle: Performance and emissions (II), *Biomass and Bioenergy, 33*, 2009, 948-956.

Rao, G. L. N., Sampath, S. & Rajgopal, K. (2008). Experimental studies on the combustion and emission characteristics of a diesel engine fuelled with used cooking oil methyl ester and its diesel blends, *International Journal of Engineering and Applied Science*, *4*, 64-70.

Singh, B., Kaur, J. & Singh, K. (2010). Production of biodiesel from used mustered oil and its performance analysis in internal combustion engine, *Journal of Energy Resources Technology*. *132*, 1-4.

Sing, S.P.& Sing, D. (2010). Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: A review, *Renewable and Sustainable Energy Reviews*, 14, 200-216.