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Performance of Waste Fried Oil based Biodiesel in a Stationary Diesel Engine

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Abstract*: The research activities related to alternative fuels has gained prominence, due to exhaustion of the present fossile fuels and rise in pollution levels. Any substitute to diesel will help mankind for safeguarding the environment due to redced usage of conventional fuels, as diesel consumption is high in goods transshipment sector and cultivation fields.Suitable replacement for diesel are Vegetable oils, because their cetane value is nearer to pure diesel. The combustion related issues with vegetable oils, either edible or nonedible can be resolved to a major extent by esterifying them.For this study the biodiesel extracted from used cooking oil, was used as fuel, in a 3.68 kW, 1500 RPM stationary diesel engine at distinct injection timings.The injection timings were changed by keeping copper shims between body of fuel pump and frame of diesel engine. The value of optimum injection timing(where maximum efficiency is obtained) was observed to be 31^0 forbiodiesel and diesel fuels. The performance parameters, combustion characteristics and pollution levels were recorded, at recommended and optimum timings of injection of 27^0 and 31^0 before the top dead centre(bTDC).Studies were conducted with pure diesel and biodiesel, made using waste fried vegetable oil (WFVOBD). The biodiesel showed equivalent performance at both manufacturer recommended and experimentally obtained optimum injection timings, but marginally increased levels of NO_x.

***Keywords* : biodiesel, performance parameters, used cooking oil, waste fried oil** .

I. INTRODUCTION

Energy has a predominant role for realising continuous progress of a nation and also for movement of goods and people. With increase in vehicles day by day and their pollution levels, the alternative fuel research has gained importance. Emissions from conventional fuels were established as a source for global warming. Increasing trends in the prices of petroleum products is a matter of concern for many nations like, India because our oil requirements are met mostly by imports. Hence initiatives in developing efficient renewable fuels results in solving pollution related problems, to conserve the conventional petroleum fuels and also for savings in imports category.

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In the entire world (as well as in India) the diesel Engines dominates commercial transportation and agricultural sectors due to their better fuel efficiency. A suitable substitute to diesel will be a great development in conservation efforts of energy. Among several substitutes available, vegetable oils (renewable in nature) hold a special promise, as their cetane value is nearer to diesel fuel and also compatible with materials used in distribution and engine fuel pipeline systems.

Many researchers reported reduction in performance, increased emissions, certain operational related and combustion problems after using vegetable oils of different origins, as fuel in compression ignition engines [1-4]. Little volatility and higher viscous nature are difficulties encountered with use of vegetable oils . These issues can be handled to a major extent by converting them into methyl esters. As demand continuously exists for edible or cooking oils and also costly, non edible oils can only be used for production of biodiesel. Even non edible oils have their own applications

Biodiesel in various proportions (0 to 100%) was used as fuel in diesel engine, by several researchers, and reported marginal improvement in performance, reduced particulate emissions but rise in levels of NO_x(Nitrogen Oxides)[5-9]. Biodiesel can be made through various sources like pongamia, jatropha, soya, mustard oil seeds etc.Now in this particular case study the biodiesel was made by Trans esterification method , from collected waste oil at various hotels and restaurants which otherwise will be disposed as waste. In this study inplace of mineral diesel the biodiesel made using wate cooking oil (WFVOBD) was tried as a total substitute in CI engine and its performance was correlated with numerical values of diesel operation at 27^0 and 31^0 bTDC.(Recommended and experimental determined optimum injection timings)

II. MATERIALS AND METHODOLOGY

Figure.1 represents the snapshot of test setup employd for experimentation with biodiesel and diesel. The engine employed was of kirloskar make with bore 80 millimeters(mm) and a stroke length of 110 mm. This engine develops a power of 3.68 KiloWatts at 1500 revolutions per minute. This is a vertical engine having one cylinder, four-stroke cycle, employing water- cooling with 16:1 compression ratio. The manufacturer has recommended 27^0beforeTop Dead Centre(bTDC) injection timing,at 190 bar pressure. The test engine was of DI(direct injection) type. The brake power was determined by connecting it to dynamometer (electrical type).

Mass of fuel was estimated by burette method and air-box method was employed for measuring air consumption.

The change in timings of injection, were achieved by introducing shims made of copper between body of the pump and engineframe. The performance was determined at recommended 190 bar pressure at 27 and 31^0bTDC values. The temperature levels of exhaust gases was found by employing suitable thermocouples. Intensity of Smoke was measured in Hartridge Smoke Units(HSU).NO_x levels in PPM were recorded by a meter which works on Chemiluminescence principle .

Fig.1.Photo of Test Setup

A special P-θ (pressure-crank angle) software records the Maximum rate of pressure rise (MRPR), the magnitude of Peak pressure levels (PP) and the value of Time of occurrening of peak valu of pressure (TOPP) with signals of crank angle and pressure, for engine full load operation.

A. Biodiesel operation on engine

The experiments involved using biodiesel made using waste fried oil gathered from several restaurants and canteens. In general the high viscous level of this type of oils is the major drawback for direct usage in a C.I. engine. When we employ vegetable oils instead of diesel,it results in several operational issues like piston rings jamming, fuel system and cylinder deposits etc. These effects can occur spanning certain duration depending upon use and fuel system design. Vegetable oils use results in reduced fuel economy and rise in exhaust emissions.[12]

To convert waste fried oil to biodiesel form,a process known as transesterification was employed The free fatty acids(FFAs) in waste fried oil should be dealt either by esterifying to methyl esters and then to transesterification or increasing catalyst quantity for transesterification process, so that additional catalyst neutralizes the FFAs,obtaining soap as extra byproduct.

III. RESULTS AND DISCUSSIONS

The performance level of the present diesel engine, was determined by altering the injection timings, by keeping copper shims between the crank case and pump body. The variation was done from 27^0–34^0 bTDC ,and performance evaluation was done at recommended and optimum (highest thermal efficiency,BTE) injection timings.

Figure.2 shows the alterations of thermal efficiency (BTE) with different mean effective pressure (bmep) for diesel, at190 bar pressure for various injection timings. BTE showed upward tendency up to eighty percentage of full load (4.2 bar) and thereafter that load ,efficiency reduced at all injection timings. The rise in engine efficiency value was because of increased fuel conversion efficiency. Reduction of thermal efficiency after 80 percentage load is because of reduced levels in values of volumetric efficiency and air fuel ratio values.Earlier researchers quoted similar observations [8, 11].

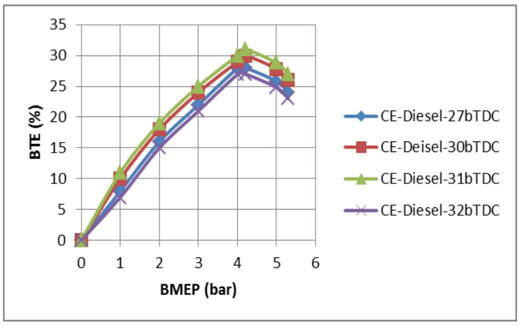

Fig.2 BTE variation for Diesel with BMEP..

BTE showed increasing trend for advancing in (towards BDC) the injection values. This trend was because of increased contact period between fuel particles and air which improved combustion. At 31^0bTDC higher value of BTE was observed. Observations of similar nature were noticed by previous researcher [12]. Performance deteriorated beyond 31^0bTDC, the reason being exceess values of delay period. Therefore 31^0, was finalized as the value of optimum timing of injection at 190 bar pressure forl diesel fuel operation.

Figure.3. represents the variation levels of efficiency for various values of BMEP for biodiesel considered for present study (WFVOBD).We can observe that biodiesel operation exhibited comparable performance to pure diesel at 270 bTDC. This was mainly due to difference between heating capacity values and viscosity of fuels. Anyhow, high density balances the energy content of the biodiesel. Leakages in plunger and fuel pump barrel were reduced, for more viscous nature of biodiesel.

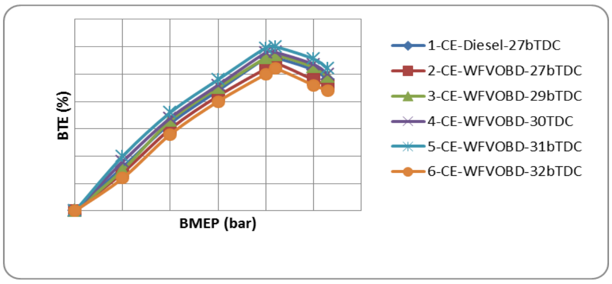

Fig.3. Variation of Efficiency for biodiesel with BMEP

Efficiency was observed to increase for biodiesel operation with advancement in injection timng, the reason being commencement of combustion at an early stage and efficient combustion because of penetration of air into fuel spray cone giving high BTE. The optimum value of injection timing was observed to be 31^0 bTDC for biodiesel operation, the reason being change in delay period Figure.4 represents the variations in efficiency values for fuels at 27^0 and 31^0 bTDC for 190 bar injection pressure. From the Fig.4, it was noticed that biodiesel operation reduced peak BTE by 4 % at 27^0bTDC and 3 % at 31^0bTDC in comparision to diesel operation.

The reason being lesser heat of combustionalong with moderate viscosity of biodiesel. This was because of the reasoning of better calorific value and more cetane no of purediesel resulting in effective combustion for producing higher thermal efficiency.

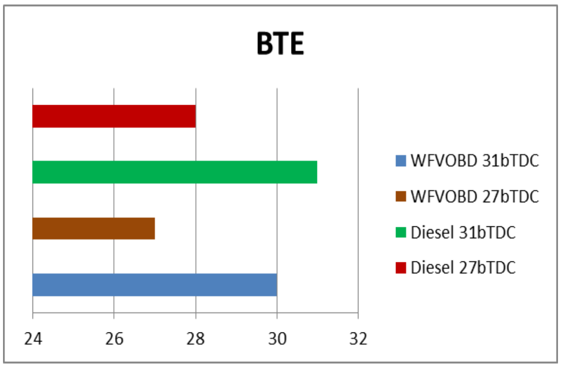

Fig4.The BTE changestwith injection timings

Figure.5 shows the changes of specific energy consumption levels(BSEC) at different values of injection timings.. It was noticed from the graph that for biodiesel operation the engine exhibited 5% increase in BSEC at 27^0 bTDC and comparable at 31^0 bTDC, with relative to diesel fuel operation.Availability of O_2 in biodiesel composition improved combustion despite more viscous nature of biodiesel. This could be taken as indication of better combustion.

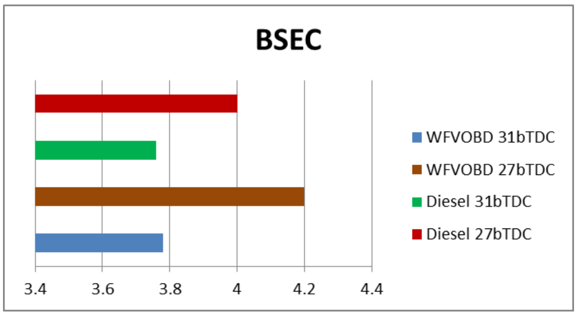

Fig.5. Variation of BSEC at different timings.

Figure 6, shows bar graph for the case of test fuels for exhaust gases temp. variatins (EGT) at 190 bar. From the chart it was noticed that biodiesel operation enhanced EGT values by around 13% and 4%, in comparision to diesel at their respective injection timings. .The reason being longer duration of combustion for biodiesel because of moderate viscosity. The magnitudes of EGT reduced with advances in injection timing, the reason being more time of contact between fuel particles and air leading to better ratios in air fuel combinations and fuel atomization characteristics. With advances of injection values,the transfer of work from piston to gases was more, thus obtaining lower temperatures for engine exhaust gases.

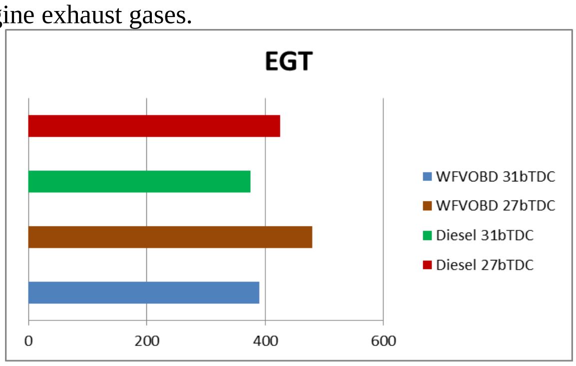

Fig.6. Variation of Exhaust Gas Temp.

The temperature levels inside the engine cyliner effects the incoming charge density, thus influencing engine volumetric efficiency. Figure 7, shows volumetric efficiency variation for different timings for fuels under consideration and one hundred and ninty bar pressure for the present stuidy

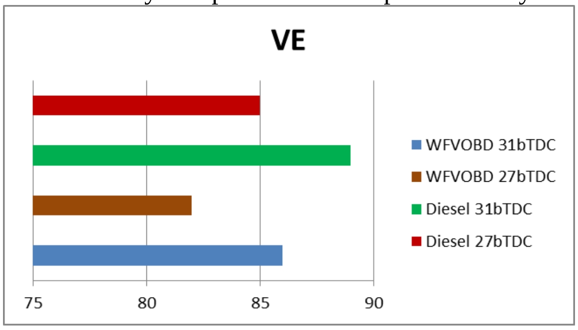

Fig.7. Volumetric Efficiency variation

From the above graph we can observe that biodiesel operation lowered volumetric efficiency by 3% at 27^0bTDCand also at 31^0bTDCtimings while correlating with operation of diesel. Comparable trends were noticed by earlier researchers[8,12].

Smoke and NO_x from diesel engines results in several health hazards, hence control of these pollutants should be an important aspect for any researcher.

Figure 8, shows the smoke level variations in Hartridge Smoke Units (HSU) at 190 bar pressure. Smoke levels in particular, directly commensurates with density of fuel. The biodiesel running exhibited in reduction of levels of smoke upto 27% and 16% at 27^0 bTDC and 31^0 bTDC respectively in reference to. Diesel operation. Reduction in smoke levels is because of inherent availability of O_2 in biodiesel leading in turn to effective combustion..

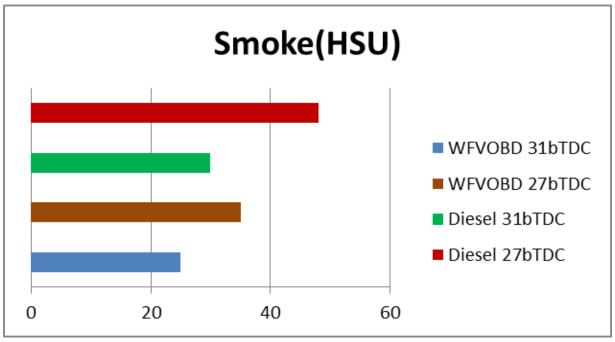

Fig.8. Smoke levels Variation in H.S.U

Smoke intensity levels were observed to comparitevely low at their respective optimum timings in comparison to recommended timings.

Atomization characteristics for fuel has increased since as of higher contact period in between air fuel mixture with immediate inception of burning.

The two complimentary situationss for generation of NO_x are peak inside cylinder temperaturescoupled with oxygen availability .Nitrogen oxide levels were more at 27^0 bTDC , the reason being magnitudes of peak pressures and huge quantum of gaseous mixture burning closer to stoichiometric ratios . Figure 9 shows variation in levels of NO_x at 190 bar pressure for injection timings under consideration. From the bar graph , we can say biodiesel operation raised nitrogen oxides by 3% and 5 % respectively at 27 and 31^0bTDC, in relation to diesel fuel operation

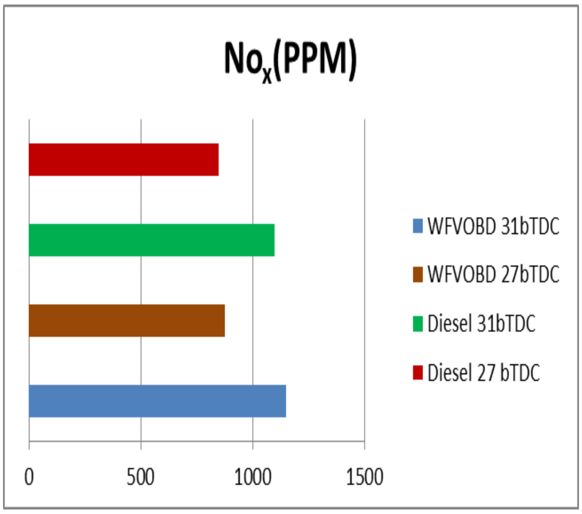

Fig.9. NO$_x$ levels variation at different timings

This rise was due to existence of 18 percent poly ~~u~~nsaturated fatty acids(PUFA) and 54.9 percent of mono unsaturated fatty acids(MUFA).Oleic and Linoleic fatty acids are mostly accountable for higher levels of NOx. Previous researchers also observed similar trends [11].

Figure 10, represents the magnitudes of in cylinder peak quantityof pressure (PP) variations at 190 bar pressure for different timings of injection under study at present.From the graph it was noticed that biodiesel operation raised PP by 4% and 3% at 27^{0}bTDC and 31^0 bTDC in reference to diesel operation. Eventhough biodiesel had lesser heating value the magnitude of peak magnitudes of pressure was higher due to more values of bulk modulus and cetane number. High density of fuel results in early lift of nozzles needle, leading to advanced injection. Therefore combustion occurs nearer to TDC(lower value of TOPP) and the magnitudeof PP is higher due to existence of smaller cylinder volume near TDC.

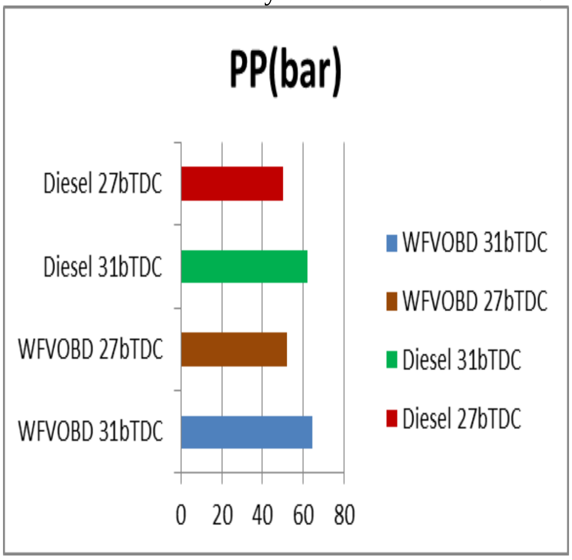

Fig.10. Peak Pressure Variation for test fuels.

The readings of Peak Pressures showed increase in trend with advancement in injection time, because of fuel gradually accumulated through delay period leading to sudden explosive type of burning during the combustion stage. The magnitudes of PP for biodiesel are high followed by diesel, even MRPR valuesalso exhibited similar trend. Figure .11 represents MRPR variation, for various injection timings in consideration and at 190 bar pressure .

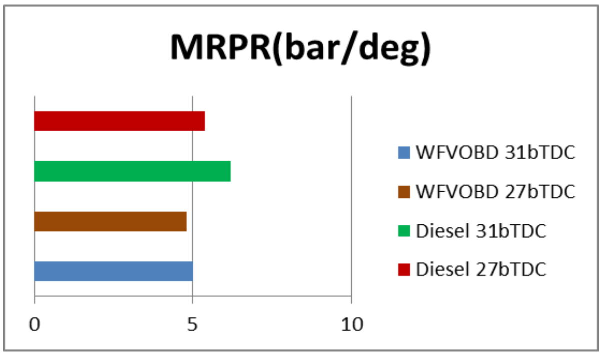

Fig.11.Variation of MRPR

Biodiesel operation reduced MRPR by 11% and 19% with reference to diesel operation. Even though the biodiesel cetane value is comparable to diesel, biodiesel is not of that much volatile nature and it has got less calorific value.

Figure 12 manifests the bar graph for TOPP, ie Time of occurrence of Peak magnitudes of Pressure for both fuels. Biodiesel functioning recorded TOPP by 11% and 12% with reference to diesel operation. The reason being the moderate delay period of biodiesel, by virtue of its moderate viscosity TOPP decreased, that means moved towards TDC when injection timings were advanced for both fuels. Better break up of atoms of fuel and earlystart of combustion phenomenon are behind this decrease.

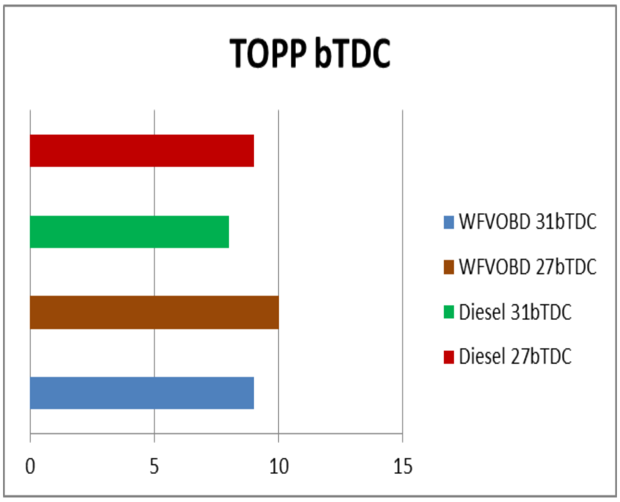

Fig.12.The variation of-TOPP

All the experimental results relative to the above discussed performance parameters are represented in the tables below.

Table-1

Sl .No	Description of the Item	BTE (%)	BSEC (kW/kW)	EGT (^{o}C)	VE (%)
1	Diesel 27^{0}bTDC	28	4	425	85
2	Diesel 31^{0}bTDC	31	3.76	375	89
3	WFVOBD 27^{0}bTDC	27	4.2	480	82
4	WFVOBD 31^{0}bTDC	30	3.78	390	86

Table-2

Sl .No	Description of the Item	SMOKE (HSU)	NO_x (PPM)	PP (bar)	MRPR (bar/deg)	TOPP (Deg)
1	Diesel 27^0bTDC	48	850	50.4	5.4	9
2	Diesel 31^0bTDC	30	1100	62.2	6.2	8
3	WFVOBD 27^0bTDC	35	875	52.1	4.8	10
4	WFVOBD 31^0bTDC	25	1150	64.4	5.0	9

IV. CONCLUSIONS AND FUTURE SCOPE OF WORK

The present Direct injection(DI) combustion chamber type diesel engine exhibited compatable performance values, reduced smoke levels for biodiesel functioning when correlated to diesel fuel, but slightly higher Nitogen oxide levels were recorded.Exhaust Gas Recirculation(EGR) technique can be employed for reduction of NO_x levels. Higher injection pressures may be employed to obtain better performance (due to better atomization of fuel).Even preheating of biodiesel to match its viscosity to that of pure diesel fuel can be tried to achieve better results.

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