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Performance and Emission Analysis of Trifuel in a Single Cylinder Four Stroke CI-Engine

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Abstract—*With modernization and increase in the number of automobiles worldwide, the consumption of diesel and gasoline has enormously increased. Even though Petro fuels play a very essential role in the earthy life, As petroleum is non-renewable source of energy and the petroleum reserves are scarce nowadays and also produces environment pollution, there is a need to search for alternative fuels for automobiles. Work has been done in using a lot of biofuels, other possible fuels etc., with a view to find out the best solution for the concern above mentioned, we seek renewable sources like LPG, turpentine oil. Both are very good alternative fuels that has similar properties as that of diesel. In the present work, experimental investigation has been carried out for calculating the performance and emission of LPG, turpentine oil blended diesel.*

1. INTRODUCTION

Depleting petroleum reserves and increasing cost of the petroleum products accelerates an intensive search for alternative fuels which can wholly or partially replace petrofuels. Biofuels are tested from times and they prove to be very good substitutes for the existing petrofuels. They require a little engine modification to be used in IC engines. Nowadays gases like LPG(liquefied petroleum gas), LNG (liquefied natural gas), LPG, etc. are being used as substitute of diesel and gasoline in IC engines. These are inducted into the engine along with the air coming into the engine. Generally, biofuels are obtained from the living plant sources.

Papagiannakis et al (2004) had conducted experimental investigations to examine the effect of dual fuel combustion on the performance and pollutant emissions of a DI diesel engine. From analysis of the experimental data, it is revealed that dual fuel operation results in lower peak cylinder pressure compared to the one under normal diesel operation, which is encouraging since no danger exists for the engine structure. At low load, the combustion duration under dual fuel operation is longer compared to normal diesel operation, while at high load, it is shorter.

Ramadhas et al (2006) conducted experiments on the partial combustion of biomass in the gasifier generated producer gas that can be used as supplementary or sole fuel for internal combustion engines. Important findings on the engine performance and environmental aspects of electric power generation in dual-fuel mode of operation using coir-path derived producer gas-rubbed seed oil are highlighted. Further, existing diesel engine was capable of successful running in dual-fuel mode of operation with biomass. However, higher the capacity of the engine than the required capacity to be selected because the producer gas dual fuel engine could run only at maximum of 50-60% of maximum load condition.

Babu et al (2003) investigated that an unprocessed oil can be used in engines, but unlike diesel fuel, vegetable oil have different physical and chemical properties, some fuel property e.g., oxidation resistance, are markedly affected by fatty acid composition of vegetable oils. The large size of vegetable oil molecules (tri or more time larger than hydro carbon fuel molecules) and the presence of oxygen in the molecule suggest differ from those of hydrocarbon fuels because of this physical and chemical property, vegetable oil accumulate and remains as charred deposits inside the engine cylinder. Similar observations was made by Clevenger, et.al.(1988) using vegetable oils and much attention have paid on viscosities of oils on engine efficiencies

Tomita et al (2000) investigated the induction of hydrogen in the intake port of the diesel engine. They found that NOx emission decreased because the combustion was lean and premixed. HC, CO, CO_2 and smoke emission also decreased with a marginal sacrifice in thermal efficiency.

Das (2002) suggested that hydrogen could be used in SI engine as well as in CI engine without any major modification in the existing system. He studied different modes of hydrogen induction carburetion, continuous manifold injection, timed manifold injection, low pressure direct injection and high pressure direct injection and suggested to use manifold injection method for the induction of gases to avoid undesirable combustion phenomenon (back fire) and rapid rate of pressure rise.

Saravanan et al (2009), carried out an experimental study on a single cylinder water cooled direct injection diesel engine using hydrogen in dual fuel mode. It was reported that the brake thermal efficiency increase from 23.59% to 29% with optimized start of injection and duration. The peak pressure increase rapidly when using hydrogen in dual fuel mode. The emissions such as NOx, CO, CO_2 and HC are reduced drastically.

Nathan et al (2008), conducted experiments in a CI engine by using acetylene as a fuel in homogeneous charge compression ignited mode along with preheated intake air. The efficiency achieved was very near to diesel, NOx and smoke level reduced considerably. However, HC level increased. They also adopted acetylene as a fuel for HCCI engine because of its moderate auto ignition temperature and high flammability limits. They varied intake charge temperature to control combustion phasing. They achieved brake thermal efficiency comparable to that of conventional CI mode by using proper intake charge temperature.

Table 1: Properties of fuels

Properties	Gasoline	Diesel	Turpentine	Hydrogen	LPG
Formula	C4 to C12	C8 to C25	C10H16	H2	C3H8
Molecular weight in kg/kmol	105	200	136	2	44.09
Density kg/m3	780	830	860-900	0.08	0.56
Specific gravity	0.78	0.83	0.86-0.9	0.07	0.509
Boiling point oC	32-220	180-340	150-180	- 252.8	-42
Latent heat of vaporization kJ/kg	350	230	305	0.904	426

Properties	Gasoline	Diesel	Turpentine	Hydrogen	LPGs
Lower heating value kJ/kg	43,890	42,700	44,000	1,20,000	46680
Flash point °C	-43	74	38	-	-60
Auto ignition temperature °C	300-450	250	300-330	572	580
Flammability limit % volume	1.4	1	0.8	4	2.3

The combustion of gaseous fuel occurs due to the flame that propagates through. Thus the dual fuel mode combines the feature of CI and SI engine. Fuel injection is the part of CI engine and the compression of charge and propagation of flame is the part of SI engine. With the use of LPG, the HC, CO, CO and smoke emissions were less as compared to diesel baseline engine. But the NOx emissions are increased significantly. In the present work we are to carry out an experimental investigation for obtaining excellent performance and emission test for trifuel such as LPG, turpentine oil blended diesel. Taking four sets of diesel, turpentine flows corresponding to fixed mass flow rate of LPG, an observations can be calculated and represented in graphical form.

2. EXPERIMENT DETAILS

The engine used in the present study is the computerized Kirloskar-make 4 stroke water cooled single cylinder diesel engine of 5.2 kW rated power. The schematic diagram of the experimental setup is shown in Fig. 1.

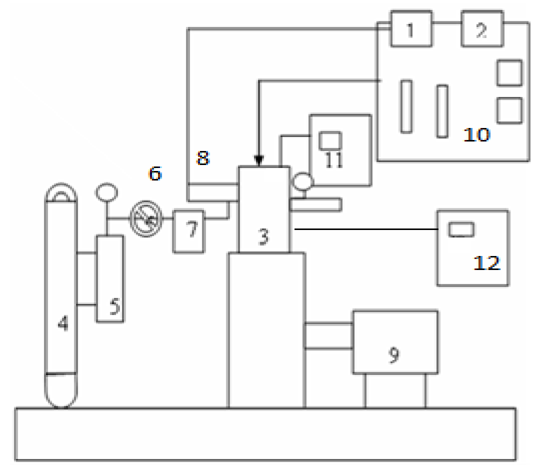

Fig. 1: Schematic diagram of experimental setup

1. Air flow meter 2. Diesel and turpentine blend fuel tank 3. Diesel engine 4.Acetylene generator

5. Flame trap 6. Flow control valve 7. Gas flow meter 8. Intake manifold 9. Dynamometer

10. Control panel 11. Oscilloscope 12. Gas analyzer.

The engine was directly coupled to an eddy-current dynamometer equipped with a load controller. The fuel flow rate, speed, load, exhaust gas temperature and gas flow rate were displayed on a personal computer.

The specifications of the engine are given in Table 3. The cylinder pressure was measured by a Piezo sensor of PCB Piezotronics Model M111A22 and the signal of the cylinder pressure was acquired for every 1°CA. Exhaust emissions were measured with an AVL DiGas 444 five gas analyser. The analyser provided a NO range of 0 to 5000 ppm with a resolution of 10 ppm, CO measurement range of 0% to 20% by volume with a resolution of 0.01%, and HC range of 0 to 20,000 ppm with a resolution of 10 ppm. The accuracy of the instrument is 10%, 5% and 0.5% of the indicated value for the measurement of NO, HC and CO respectively. As for smoke measurement, the automatic NETEL NPMCH1 smoke meter was employed. The smoke intensity was measured as light absorption coefficient (m−1). The display range, scale resolution, repeatability, response time and warm up time of smoke meter are 0–9.99 m−1, 0.01 m−1, 0.1m−1, 0.3 s and 3 minutes respectively.

Initially, the engine was started with the diesel and turpentine fuel blend and allowed to warm up. Acetylene fuel was then supplied to the intake manifold at the fixed flow rate of 2lpm through a gas flow meter, which was at equivalence ratio of 0.13. The load on the engine was increased. The quantity of the injected diesel fuel was automatically varied by the governor attached to it, which maintained the constant engine speed at 1500 rpm throughout the experiment. Table 1 shows the engine specifications..

Table 1: Specifications of test engine.

Parameter	Specification
Model	Kirloskar TV-1
Type	Single Vertical cylinder,four stroke,constant speed,bowl in piston,DI Diesel Engine
Capacity	661 cc
Bore and stroke	87.5mm*110mm
Compression ratio	17.5:1
Speed (constant)	1500 rpm
Rated power	5.2 kw
Loading type	Eddy current dynamometer
Injection pressure	200bar

3. RESULTS AND DISCUSSIONS

The maximum brake thermal efficiency obtained in the tri-fuel mixture concept is 33 % and it is by 6% higher than that of the standard other fuel systems.

Table 2: Brake thermal efficiency of standard fuel and tri-fuel mixture.

S.No.	Load in %	Break thermal efficiency in %		
		Diesel alone	Standard fuel	Trifuel mixture
1	20	12.87	14.11	12.65
2	40	19.6	20.65	20.51
3	60	24.19	28.12	29.62
4	80	26.93	31.64	32.6
5	100	27.18	32.09	33.15

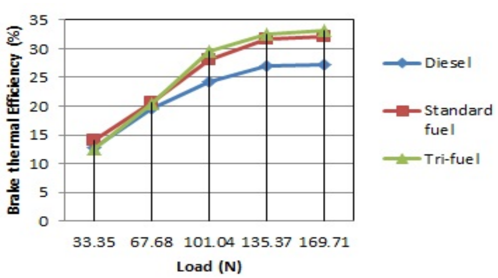

Fig. 2: Load vs Brake thermal efficiency

Table 3 CO emission of Standard fuel and Tri-fuel mixture

S. No.	Load in %	CO Emissions in %		
		Diesel alone	Standard fuel	Trifuel
1	20	35	31	26
2	40	30	26	22
3	60	35	32	26
4	80	40	38	32
5	100	70	68	59

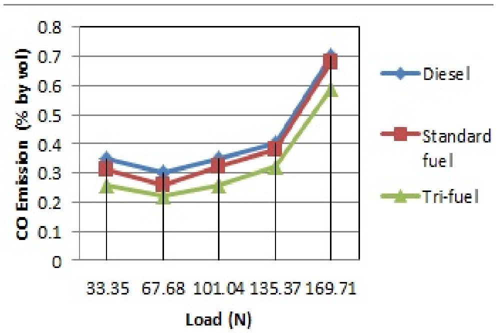

Fig. 3.Load vs CO emission

Table 4: HC emission of Standard fuel and Tri-fuel mixture

S. No.	Load in %	HC Emissions in ppm		
		Diesel alone	Standard fuel	Trifuel
1	20	75	74	70
2	40	70	69	67
3	60	100	94	92
4	80	145	139	130
5	100	240	232	225

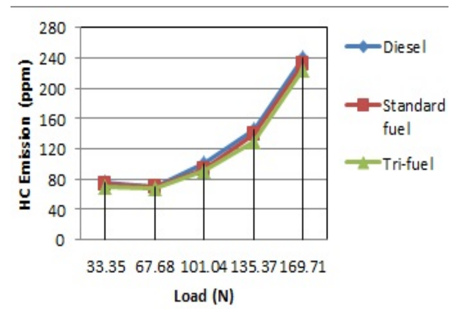

Fig. 4: Load vs HC emission

Table 4: NOx emission of Standard fuel and Tri-fuel mixture

S. No.	Load in %	NOx Emissions in ppm		
		Diesel alone	Standard fuel	Trifuel
1	20	350	336	278
2	40	600	598	567
3	60	925	894	862
4	80	1190	1161	1107
5	100	1400	1310	1297

Compared CO emissions of tri-fuel mixture concept with the standard fuel operation. It showed that the amount of CO emissions of the tri-fuel is lower than that of standard fuel and all other systems at all loads. This is due to the complete burning of the fuel and reduction in overall C/H ratio of the total supplied fuel.

It has been visualized that the amount of HC emissions for the tri-fuel mixture is lower than that of all other fuel systems at all loads.

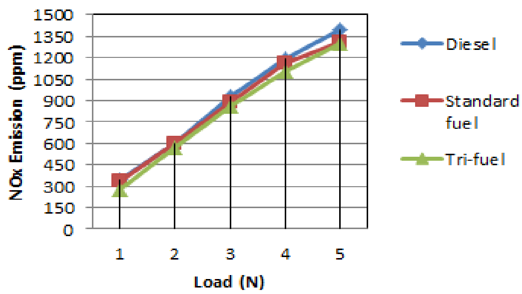

Fig. 5: Load vs NOx emission

Table 5 shown that the amount of NO_x emission of the tri-fuel mixture is lower than in the case of standard fuel due to the complete combustion of LPG

4. CONCLUSION

The tri-fuel mixture concept (acetylene aspiration in the inlet manifold up to 2 lpm and mixing of turpentine with diesel fuel upto 40%) results in the brake thermal efficiency increased by 1 to 3 % in the standard diesel fuel. It also exhibits a lower exhaust gas temperature compared with the diesel operation. Comparatively a slighter increase in NOx emissions was found and approximately 40% of smoke reduction is achieved with the tri-fuel mixture concept operation. An appreciable reduction in HC, CO and CO2 emissions was observed in the tri-fuel mixture concept with an increase in engine performance without much worsening its emissions.

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