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Experimental investigation on performance, combustion and emission characteristics of four stroke diesel engine using diesel blended with alcohol as fuel

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A B S T R A C T

In today's application, it is obligatory to formulate the use of diesel in an environmentally benevolent manner. So, in this experimental study, an attempt was made to increase the performance and reduce the exhaust emission by blending various alcohols such as n-propanol and n-butanol separately at different proportions like 4% and 8% by volume with diesel, also to compare the effect of blending n-propanol and n-butanol separately with diesel, on performance, combustion and emission characteristics. The performance, combustion and emission characteristics observed while using blended fuels were analyzed and compared with that of diesel as fuel without adding alcohols. From the performance analysis, it was reported that, at 80% load, the brake thermal efficiency was increased by 1.579%, 7.635%, 8.917% and 10.518% for the addition of 4% n-propanol, 8% n-propanol, 4% n-butanol and 8% n-butanol with diesel respectively. The emission test concluded that, the smoke density was increased by 12.891%, 5.078%, 11.338% and 14.063% for the addition of 4% n-propanol, 8% n-propanol, 4% n-butanol and 8% n-butanol with diesel respectively. The NO_x emission was decreased by 6.098%, 19.665%, 11.585% and 14.329% for the addition of 4% n-propanol, 8% n-propanol, 4% n-butanol and 8% n-butanol with diesel respectively.

1. Introduction

In this day and age, the use of diesel engine plays an important role even though the environmental aspects do not recommend the use of diesel. Therefore it is necessary to devise the use of diesel in an environmentally benign way. The emission from the diesel engines is the foremost pollutant in the present world, seriously disturbing the living beings. This work was aimed at to study the effect of using alcohol blended with diesel as fuel on performance, combustion and emission characteristics of a four stroke diesel engine.

Various researches had already been made to improve the performance and reduce the emission by adopting different approaches such as.

- using neat bio-diesel,
- adding different bio-diesels with diesel at different proportions,
- doing some modifications in the fuel supply system and in the combustion chamber, and
- blending various additives with diesel.

It was reported that the combustion of diesel in a compression ignition engine occurs in three major stages like ignition delay, premixed combustion phase and diffusion combustion phase. Among these, the ignition delay period which is the time period between the starting of injection and the onset of combustion has major influence on all ignition processes [1].

Many experimental investigations have been made by using vegetable oils as fuel in diesel engines. The results of various experimental investigations on diesel engines using different vegetable oils as fuel concluded that, there was a reduction in thermal efficiency and NO_x emission, increase in CO and HC emissions. The reduction in exhaust gas temperature and NO_x emission with a slight increase in CO emission while using diesel blended with vegetable oil as fuel were observed by some researchers [2]. The use of palm oil as fuel in compression ignition engines concluded that the short term use of palm oil enhanced the

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performance and emission levels significantly, and the prolonged use caused the carbon deposition and sticking of piston rings. The use of preheated vegetable oil increased the engine performance with lower carbon deposits [3].

The use of cotton seed oil as fuel, without any modifications in the engine, reported that the engine parameters needed re-adjustments in order to have maximum output power and highest thermal efficiency. The experimental study on a direct injection compression ignition engine while using honge, neem and sesame oil methyl esters as fuel reported that the performance and emission characteristics were almost similar to those of the engine while using diesel as fuel [4]. The high viscosity of biodiesel reduced the engine torque and engine power, also the lower calorific value of biodiesel resulted in the increase in specific fuel consumption and decrease in combustion temperature [5]. The experimental investigation on diesel engine while using linseed oil and mahua oil with diesel, revealed that blending of 50% linseed oil with diesel increased the smoke density and reduced the brake specific energy consumption, and also concluded that the mixing of 30% mahua oil with diesel reduced the smoke density and increased the brake thermal efficiency as compared to diesel [6].

Besides finding substitutes and supplements for diesel efficiency, researchers turned their attention towards the modifications in the engine itself for improving the performance, combustion and emission characteristics of the engine. The use of exhaust gas recirculation technique resulted in the reduction of NO_x emission to some extent [7]. Some experimental investigations based on advancing the injection timing and increasing the injection pressure concluded that there was an appreciable increase in brake thermal efficiency and decrease in the emission of CO, HC and smoke [8]. The dual fuel concept was also applied to improve the performance and to reduce the smoke level.

In recent years, significant attention has been given on the use of alcohols as additive with diesel. The use of alcohols along with diesel in a compression ignition engine has its own limitations due to the high latent heat of vaporization and long ignition delay period [9]. However, it was reported that the NO_x emissions could be reduced considerably with an increase in brake thermal efficiency by blending alcohols with diesel in proper proportion [10]. The bioethanol derived from vegetable oils was considered as a suitable alternate fuel because of its better spark igniting characteristics [11]. The blending of bioethanol with diesel considerably reduced the emission of green house gas [12]. The use of biodiesel blended with alcohols concluded that there was an increase in brake thermal efficiency and decrease in CO, HC and NO_x emissions [13]. Some experimental investigations using diesel blended with oxygenate additives reported that there was an increase in brake thermal efficiency and decrease in CO, HC and smoke emissions [14].

In this experimental study, n-propanol and n-butanol were identified as additives and blended separately with diesel in different proportions like 4% and 8% by volume. At different load ranges, the various performance, combustion and emission characteristics of the diesel engine while using diesel blended with 4% n-propanol, 8% n-propanol, 4% n-butanol and 8% n-butanol were evaluated. The various performance, combustion and emission characteristics of the engine thus evaluated were analyzed and compared with those of the engine while using normal diesel as fuel.

2. Methodology

2.1. Materials used

The normal diesel, which is derived from petroleum oil containing 75% saturated hydrocarbons and 25% aromatic hydrocarbons, supplied by Indian Oil Corporation was procured from the retail distributor. The normal diesel contains 0.5% sulfur, 0.02% water and 0.01% ash. The n-propanol and n-butanol of 99.5% pure with 0.1% water content supplied by Kemphasol Limited, Mumbai was taken for blending with diesel. In general, the alcohols chosen as additives have lesser calorific value, specific gravity, kinematic viscosity and cetane number, and higher latent heat of vaporization when compared with that of diesel. The different blended fuels were prepared by mixing n-propanol and n-butanol separately with diesel at different proportions like 4% and 8% by volume. The complete blending of alcohols with diesel was done with the help of a mechanical stirrer. The various properties as per ASTM standards of diesel, n-propanol and n-butanol obtained from the supplier's catalog were given in Table 1.

2.2. Experimental set-up

A stationary single cylinder four stroke diesel engine with the specifications mentioned in Table 2 was used for experimentation.

The engine was coupled with an eddy current dynamometer as loading device. A computerized data acquisition system was attached with the engine for measuring various performance and combustion parameters like fuel flow rate, engine speed, incoming air and exhaust gas temperature, pressure inside the cylinder, maximum heat release rate, cumulative heat release, etc. The AVL 619 Indimeter software, which is easy and having menu driven parameter editing option for setting up the system, supported the data acquisition system. By using an AVL make piezoelectric air cooled transducer mounted on the engine cylinder head, the pressure inside the cylinder was measured. In the crank angle encoder, a crank degree marker, an electromagnetic pickup and a signal processing unit were used. The AVL 444 Di gas exhaust gas analyzer manufactured by AVL, Austria was used to measure the presence of CO, HC and NO_x in the exhaust. The AVL 413 smoke meter was also used to measure the smoke density.

The layout of the experimental setup was shown in Fig. 1.

2.3. Experimental procedure

Initially, the engine was started at no load conditions by using normal diesel as fuel. After the engine getting warmed-up, by running it for a period of minimum 3 min, the load was applied through eddy current dynamometer at the rate of 20% of full load, and the engine was allowed to run for a period of minimum 3 min to reach equilibrium conditions. After reaching equilibrium condition, the various performance, combustion and emission characteristic parameters were observed and recorded. In order to get reliable readings, all the experimental investigations were carried out at a constant surrounding temperature.

The load was then amplified to 40% of full load and the engine was allowed to run for sufficient time to reach the equilibrium condition, then the various characteristic parameters were observed and recorded as per the standard procedure. By following the same procedure, various parameters were observed and recorded for higher loads such as 60%, 80% and 100% of full load.

Table 1
Properties of diesel, n-propanol and n-butanol.

S. No.	Property	Unit	Diesel	n-propanol	n-butanol
1.	Molecular formula	–	$C_{12}H_{23}$	C_3H_7OH	C_4H_9OH
2.	Lower calorific value	kJ/kg	43,200	30,680	33,075
3.	Specific gravity at 40 °C	–	0.83	0.802	0.81
4.	Kinematic viscosity at 40 °C	cSt	4.3	2.8	3.64
5.	Latent heat of vaporization	kJ/kg	250	779	585
6.	Cetane number	–	49	15	15