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Effect of diethyl ether on Tyre pyrolysis oil fueled diesel engine

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HIGHLIGHTS

▶ A method of converting of scrap tyres to Tyre pyrolysis oil (TPO) is explained in this paper.
▶ A way to utilise TPO as a fuel in diesel engines is described.
▶ The utilisation of TPO which is a low cetane fuel with an ignition improver on a dual fuel mode.

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ABSTRACT

Tyre pyrolysis oil (TPO) can be derived from waste automobile tyres by different methods and it can be used as a fuel blended with diesel in a diesel engine. In the present work, a study was made to use Tyre pyrolysis oil derived from vacuum pyrolysis oil as a fuel in a diesel engine with the help of an ignition improver. Experiments were conducted on a single cylinder four stroke DI diesel engine using TPO as a main fuel. The performance, emission and combustion characteristics of the DI diesel engine were investigated and compared with the conventional diesel fuel (DF). Diethyl ether (DEE) was admitted along with intake air at three flow rates viz 65 g/h, 130 g/h and 170 g/h. Results indicated that the engine performs better with lower emissions when DEE was admitted at the rate of 170 g/h with TPO. It was observed that NO_x emission in TPO–DEE operation reduced by 5% compared to diesel fuel operation. HC, CO and smoke emissions were higher for TPO–DEE operation by 2%, 4.5% and 38% than diesel mode.

1. Introduction

Rapid depletion of petroleum fuels and environmental issues have made the fuel market to awake and find alternative solutions for the petroleum fuels used in mobility, power and agriculture sector. This has intensified the search for alternative fuels for internal combustion engines. One of the methods to derive alternative fuels is pyrolysis in which waste substances are converted into useful energy [1,2]. Biomass-based fuels like methanol and ethanol etc., are some of the examples in which waste-to-energy is adopted, and these are used as alternative fuels for internal combustion engines. Attempts were also made to use wood pyrolysis oil and rubber pyrolysis oil as fuels in diesel engines [3–5]. Various methods were adopted to convert waste automobile tyres into Tyre pyrolysis oil and fuel analysis was done [6–13]. Tyre pyrolysis oil was produced in a laboratory scale by vacuum pyrolysis method [13,14]. The elemental composition of TPO obtained in the present work is given in Table 1. The oil collected for this study was untreated and it contains both low and high volatile fractions. The properties of TPO compared with reference fuel (diesel) are given in Table 2. The carbon content present in a hydrocarbon fuel is very important as it indirectly indicates the energy content of the fuel. The carbon content of TPO is lesser than DF and hence the calorific value is also lesser than DF. The ash content of TPO is higher than DF. The presence of ash content in a fuel can result in wear in injector, fuel pump, piston and piston ring, if it is used as a neat fuel. Blending TPO with diesel fuel may reduce this problem to a certain extent.

The performance, emission and combustion study was made on a single cylinder, four stroke, air cooled DI diesel engine using different blends of TPO and diesel fuel (10–70% at 20% interval on volume basis). The engine was able to run up to 70% TPO blended with 30% DF [15]. But the engine was not able to run with 100% TPO. The probable reason may be due to lower cetane number of the fuel that resulted in a longer ignition delay thereby delaying the start of combustion.

Fuels with very high cetane numbers can reduce the ignition delay to a greater extent. There are number of fuels such as dimethyl ether, diethyl ether and diglyme whose cetane numbers

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Table 1
Elemental composition of DF and TPO.

Elemental composition (%)	DF	TPO
Carbon	87.4	81.18
Hydrogen	12.5	10.92
Oxygen	0	4.62
Nitrogen	0.18	1.85
Sulphur	0.02	0.031

Table 2
Comparison of TPO with diesel (DF).

Property	ASTM test method	DF	TPO
Flash point (°C)	D93	50	43
Density @ 15 °C (kg/m^3)		0.8	0.935
Kinematic viscosity @40 °C (cSt)	D445	2	3.2
Calorific value (MJ/kg)		43.8	38
Sulphur (wt.%)	D2622	0.29	0.72
Carbon residue	D4530	0.35	
Ash content (%)	D482	0.01	0.31

are greater than diesel. Out of these fuels, diethyl ether is found to be the most potential fuel. Diethyl ether (DEE) has a cetane number greater than 125. Dimethyl ether is more volatile than diethyl ether and is prone to create vapour lock problems in the fuel lines. Diglyme is also a high cetane fuel that can be used as an ignition enhancer but it is costly. The fumigation technique offers the advantages of easy conversion of the diesel engine to work in the dual fuel mode. Research works on dual fuel mode with volatile fuels, vegetable oils and low cetane fuels as injected fuel and gaseous fuels or ignition improvers as inducted fuel were well documented by many researchers [16–23]. Dual fuel mode also offers increased thermal efficiency and reduced smoke emissions.

Experimental investigations were carriedout with ethanol as injected fuel and DEE as an ignition improver, in a single-cylinder, air-cooled, DI diesel engine producing 4.4 kW of power at 25 r/s in a dual fuel mode [24]. The DEE aspirated into the intake air was varied gradually to achieve a constant speed of 25 r/s at various loads. The quantity of DEE was progressively adjusted in such a way that the lower level of DEE was determined by the onset of unstable operation or misfiring and knocking observed from the pressure–crank angle diagram. It was reported that the engine can run smoothly over the entire range of loads, by the introduction of about 3% DEE. The brake thermal efficiency was found to be higher for ethanol with DEE than with diesel fuel operation. The ignition delay for ethanol–DEE was longer than that of diesel fuel at rated load. The CO and HC emissions were higher for ethanol–DEE than that of diesel fuel. The smoke and NO_x emissions were lower for ethanol–DEE than that of diesel fuel.

Experimental investigations were carried out on a Volvo AH10A245 bus engine, using ethanol fuel as a main fuel and DEE was fumigated along with intake air [25]. In this study, DEE was used as an ignition improver. The cylinder pressure increased extensively with increase in DEE. The heat release evolution indicates earlier ignition, i.e. shorter ignition delay, and lower peak heat release for a higher flow of DEE. Such performance resulted in smooth running of the engine and low noise as well. It was also reported that hydrocarbon (HC) and carbon monoxide (CO) increased, and the NO_x level decreased with increase in DEE.

The combustion, performance, and emission characteristics of a direct-injection (DI) diesel engine were studied using orange oil and diethyl ether (DEE) [26]. DEE was inducted as an ignition improver through the induction manifold and orange oil was injected into the engine through a conventional fueling device as a primary fuel. It was noticed from the results that the performance of the orange oil–DEE fuel was better than that of diesel fuel. The peak cylinder pressure and heat release rate were found to be higher for the orange oil–DEE fuel than those of diesel fuel. The hydrocarbon and carbon monoxide emission levels in the engine exhaust increased with orange oil–DEE compared with those of diesel fuel. The smoke and NO_x emissions were lower with orange oil–DEE compared with diesel fuel. It is concluded that a diesel engine operated using orange oil–DEE gives simultaneous reduction in NO_x and smoke emissions with better performance.

An investigation was conducted to study the influence of a cetane number improver on the heat release rate and emissions of a four-cylinder, high-speed diesel engine fueled with ethanol–diesel blend [27]. Different percentages of cetane number enhancer (0%, 0.2%, and 0.4%) were added to the blend. The results showed that: the brake specific fuel consumption (BSFC) increased, the thermal efficiency improved remarkably, and NO_x and smoke emissions decreased simultaneously. Combustion characteristics that are comparable with those of the diesel engine are attained at high loads in ethanol–diesel blend operation if a cetane number improver is used. The combustion parameters of ignition time, combustion duration, and maximum heat release rate show a marginal difference, because the large evaporation heat of ethanol results in higher temperature reduction at low loads with a cetane number improver. Also reported is that CO emission increases remarkably at lower and medium loads with a cetane number improver.

In the present investigation, TPO was injected into the cylinder as the main fuel and DEE was inducted at three different flow rates into the cylinder along with intake air. The combustion performance and emission parameters of a single cylinder, four stroke, air cooled, DI diesel engine developing power of 4.4 kW at 1500 rpm was evaluated in comparison with diesel fuel operation.

2. Experimental setup

The schematic layout of the experimental setup is shown in Fig. 1. The specifications of the engine are given in Table 3. An electrical dynamometer was used to provide the engine load. An air box was fitted to the engine for airflow measurements. The fuel flow rate was measured on volumetric basis using a burette and a stopwatch. Chromel alumel thermocouple in conjunction with a digital temperature indicator was used to measure the exhaust gas temperature. A pressure transducer in conjunction with a KISTLER make charge amplifier and a Cathode Ray Oscilloscope (CRO) was used to measure the cylinder pressure. The pressure pickup was mounted on the cylinder head and before mounting it was calibrated with a dead weight tester. A TDC optical sensor with a signal conditioner was used to detect the engine crank angle.

A plastic container storing DEE was connected to a burette through a stopcock. From the burette, the DEE was allowed to flow through a valve needle of 2 mm diameter directly into the intake pipe located at 5 cm before the inlet manifold. The DEE was admitted into the intake pipe in the form of droplets. The properties of DEE are given in Table 4. As DEE is highly volatile, it readily mixes with the air drawn and enters into the cylinder. The engine started easily with TPO.

The time taken for DEE and TPO were recorded to determine the flow rates. Experiments were conducted at various flow rates of DEE viz 65 g/h, 130 g/h and 170 g/h and were maintained in such a way that the onset of unstable operation or misfiring and knocking was observed from the pressure crank angle trace. The quantities of DEE required for starting the engine and for idling was 16.5% by mass. A gas analyzer was used to measure NO_x/HC/CO emissions in the exhaust. The accuracy of the instrument is ±1 ppm. Smoke was measured by a Bosch smoke meter. Initially experiments were carried-out using diesel fuel (DF). All the experiments were con-