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Performance evaluation of medium grade low heat rejection diesel engine with carbureted methanol and crude jatropha oil

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ABSTRACT

Vegetable oils and alcohols (ethanol and methanol) are important substitutes for diesel fuel as they are renewable in nature. However drawbacks associated with vegetable oils (high viscosity and low volatility) and alcohols (low cetane number) call for engine with hot combustion chamber with its significant characteristics of higher operating temperature, maximum heat release, higher brake thermal efficiency (BTE) and ability to handle the lower calorific value fuel. Methanol was inducted into the engine through a variable jet carburetor, installed at the inlet manifold of the engine at different percentages of crude vegetable oil at full load operation on mass basis. Crude vegetable oil was injected at near end of compression stroke. Performance was evaluated with engine with LHR combustion chamber consisting of air gap (3mm) insulated piston with superni (an alloy of nickel) crown and air gap insulated liner with superni insert with mixture of carbureted methanol and crude vegetable oil with varied injector opening pressure and injection timing. Comparative studies were made with crude vegetable oil operation on engine with LHR combustion chamber at similar operating conditions. Performance parameters and exhaust emissions were determined at various values of brake mean effective pressure. Aldehydes were measured by the 2,4, dinitrophenyl hydrazine (DNPH) method. Combustion characteristics were measured with top dead center (TDC) encoder, pressure transducer, console and special pressure–crank angle software package at full load operation of the engine.

The optimum injection timing with crude vegetable oil operation on LHR combustion chamber was 29° bTDC. The maximum induction of methanol was 55% at recommended injection timing (27° bTDC), while it was 50% at optimum injection timing. With maximum induction of methanol, at an injector opening pressure of 190 bar, at recommended injection timing, engine with LHR combustion chamber increased peak brake thermal efficiency by 6%; at full load operation it decreased brake specific energy consumption by 2%, exhaust gas temperature by 16%, coolant load by 11%, volumetric efficiency by 6%, sound levels by 8%, particulate matter by 45%, NO_x emissions by 46%, increased formaldehyde emissions and acetaldehyde emissions drastically, increased peak pressure by 23% and maximum rate of pressure rise by 17% when compared with crude jatropha oil operation at similar operating conditions.

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1. Introduction

In the context of depletion of fossil fuels, ever increase of fuel prices in International Market causing economic burden on developing countries, increase of pollution levels with fossil fuels, the search for alternative fuels has become pertinent. It has been found that vegetable oils are promising substitute for diesel fuel, because their properties are comparable to those of diesel fuel. They are renewable and can be easily produced.

Rudolph Diesel, the inventor of the diesel engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil [1]. Several researchers experimented the use of vegetable oils as fuel on CE and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character causing piston ring sticking, injector and combustion chamber deposits, fuel system deposits, reduced power, reduced fuel economy and increased exhaust emissions [2–10].

On the other hand alcohols are renewable and volatile fuels. There are many methods of inducting alcohols in diesel engines, out of which blending and carburetion techniques are simple. Investigations were carried out with blended alcohol with diesel fuel in conventional engine and reported performance improved with blends [11–15]. Exhaust emissions of particulate matter and nitrogen oxides (NO_x) decreased in comparison with pure diesel operation on conventional engine.

However, methanol has a low cetane number (less than 10). Hence engine modification is necessary if carbureted methanol is used as fuel in diesel engine. The drawbacks associated with the crude vegetable oil and methanol as fuels in diesel engine call for hot combustion chamber provided by LHR combustion chamber.

The major concept of engine with LHR combustion chamber is to reduce heat loss to the coolant, by providing thermal insulation in the path of heat flow to the coolant. Engines with LHR combustion chamber are classified depending on the degree of insulation, such as ceramic coated combustion chambers (low grade), air gap insulated combustion chambers (medium grade) and combination of these two (high grade).

Experiments were conducted on engine with medium grade LHR combustion chamber with vegetable oils with varied injector opening pressure and injection timing [16–18]. It was reported from their investigations that medium grade LHR combustion chamber improved the performance in comparison with pure diesel operation on conventional engine. However, it drastically increased NO_x emissions. Studies were also made with carbureted alcohols (ethanol/methanol) on medium grade LHR combustion chamber with diesel operation [19–21]. Alcohol (ethanol/methanol) was inducted into the engine by means of variable jet carburetor at different percentages of diesel fuel at full load operation and diesel was injected in conventional manner at the end of compression stroke. Exhaust emissions of particulate matter and NO_x levels decreased with the carburetion technique. The advantage of this method over the previous method was that more amount of alcohol (ethanol/methanol) can be inducted into the engine. It was reported that optimum induction of alcohol (ethanol/methanol) was 35% with conventional engine and 50% with medium grade LHR combustion chamber with diesel operation on mass basis.

Carbureted alcohols were used in engine with high grade LHR combustion chamber with vegetable oils and reported that performance improved with LHR combustion chamber [22–24].

In order to take advantage from high cetane number and high volatility, both vegetable oils and alcohols have to be used in engine with LHR combustion chamber.

The present paper attempted to evaluate the performance of the engine with medium grade LHR combustion chamber, which consisted of air gap insulated piston and air gap insulated liner with crude jatropha oil (CJO), with carbureted methanol, with varied injector opening pressure and injection timing and compared with crude jatropha oil at the similar operating conditions.

2. Material and method

Fig. 1 shows the assembly details of air gap insulated piston and air gap insulated liner. Engine with LHR combustion chamber contained a two-part piston; the top crown made of low thermal conductivity material, superni-90 screwed to aluminum body of the piston, providing a 3 mm-air gap in between the crown and the body of the piston. The optimum thickness of air gap in the air gap piston was found to be 3 mm for improved performance of the engine with superni insert with diesel as fuel [16]. A superni-90 insert was screwed to the top portion of the liner in such a manner that an air gap of 3 mm was maintained between the insert and the liner body. At 500 °C the thermal conductivities of superni-90 and air are 20.92 and 0.057 W/m K respectively.

The schematic diagram of the experimental setup used for the investigations on the engine with LHR combustion chamber with jatropha oil and carbureted methanol is shown in Fig. 2. The specifications of the experimental engine are given in Table 1.

The combustion chamber consisted of a direct injection type with no special arrangement for swirling motion of air. The engine was connected to an electric dynamometer for measuring its brake power. Methanol was inducted through the variable carburetor jet, located at the inlet manifold of the engine at different percentages of vegetable oil by mass basis and crude vegetable oil (CJO) was injected in the conventional manner. Two separate fuel tanks and buret arrangements were made for measuring crude jatropha oil and methanol consumptions. Air-consumption of the engine was

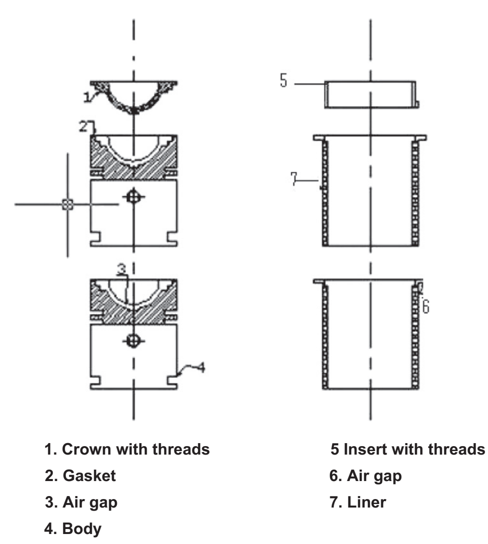

Fig. 1. Assembly details of air gap insulated piston and air gap insulated liner.