EXPERIMENTAL STUDY ON JATROPHA-PALM DIESEL BLENDS AS ALTERNATIVE FUELS

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SUMMARY: This paper presents experimental results carried out to evaluate fuel consumption, exhaust gas temperature and the emissions characteristics of jatropha-palm diesel blends in an internal combustion engine. A total of two fuel samples such as (i) 100% diesel fuel (D100) and (ii) 5% jatropha and 5% palm diesel (methyl ester of palm oil) with 90% diesel fuel (J5P5) were used. The D100 was used for comparison purposes. The details physicochemical properties of J5P5 has been measured and compared with D100 fuel. The emission parameters measured are carbon monoxide (CO), carbon dioxide (CO2), hydrocarbon (HC), smoke and oxides of nitrogen (NOx). The emissions were measured using two exhaust gas analyzers namely, Bacharach and Bosch gas analyzers. A single cylinder engine - dynamometer test bed was used to conduct this test. The test conducted with a constant engine rpm of 2000 for various brake mean effective pressures. The test results show that the combination palm diesel (methyl ester of palm oil) and jatropha (as non edible oils) blend gives prominent results through reducing emissions. Along the emission and physicochemical properties, fuel consumption and exhaust gas teperature results have also been presented with details discussion.

1. INTRODUCTION

Diesel engine sector forms a vital part of transportation systems in all the developed and developing countries of the world. Globally, the increasing use of fossil fuels has resulted in enormous increase of global environmental degradation effects. These impacts include global warming, air quality deterioration, ozone depletion, oil spills, and acid.

In several studies, it has been experimentally investigated that the human health hazards are associated with exposure to diesel exhaust emissions (Törnqvist and Ehrenberg, 1994, Iwai et al., 2000, Dybdahl et al., 2004, EPA, 2002, Vincent, 2003). Concerns over climate change from use of fossil fuels and energy security are increasing with each passing day. In this respect, there are active research programs to reduce reliance on fossil fuels by the use of alternative and sustainable fuel sources, and thus to increase the time over which fossil fuels will still be available (Namasivayam et al., 2010).

Interests in emission control systems, alternative fuels and new fuel formulations for diesel engines have significantly increased around the world regarding the new regulations and increasing demands on diesel engine manufacturers. Therefore, with limited fossil fuels, and intensified environment pollution, it became a global issue to develop such clean fuel which is

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technically feasible, domestically available and environmentally acceptable (Liaquat et al., 2010). As an alternative to petroleum-based transportation fuels, bio-fuels can help to reinforce energy security and reduce the emissions of both greenhouse gases (GHGs) and urban air pollutants (Balat and Balat, 2010).

Many studies have concluded that alternative engine biodiesel fuels reduce the emissions of carbon monoxide (CO), hydrocarbon (HC), sulphur dioxide (SO_2), polycyclic aromatic hydrocarbons (PAH), nitric polycyclic aromatic hydrocarbons (nPAH) and particulate matter (PM) but NOx to increase in the exhaust compared with diesel fuel (Oener and Altun, 2009). Similarly experimental use of blends of vegetable oils with diesel has been examined successfully by various researchers in several countries (Pramanik, 2003, Forson et al., 2004, Nwafor and Rice, 1996, Ramadhas et al., 2005, Rakopoulos et al., 2006). However major disadvantage of vegetable oil is its viscosity, which is considerably higher than that of mineral diesel (Agarwal and Rajamanoharan, 2009). Because of high viscosity and low volatility of vegetable oils, the brake thermal efficiency of vegetable oils is inferior to those of diesel. This leads to problems of high smoke, HC and CO emissions (Devan and Mahalakshmi, 2009).

The idea of using vegetable oil as the fuel for diesel engine is not new. Rudolf Diesel first used peanut oil as a fuel for demonstration of his newly developed compression ignition (CI) engine in year 1910. But soon afterwards, the application of vegetable oils as fuel was dropped due to the cheap supply of petroleum based fossil fuels available in the world.

During the period of World War-II, vegetable oils were again used as fuel in emergency situations when fuel availability became scarce (Agarwal and Rajamanoharan, 2009). Crops, which produce oil directly, are one of alternative sources of fuel.

Recently, there is a comment on biodiesel obtained from edible oils sources such as edible oils are food products and should not be used as alternative fuels in machinery systems.

In this investigation, non edible oil such as jatropha has been blended with palm diesel to operate internal combustion engine. Maximum 5% edible oils which may be obtained from waste food products added with non edible oils would be fine to partially replace fossil diesel fuel with reducing huge exhaust emission. It has been reported that among the vegetable oils, Jatropha oil exhibits very good properties. It is non-edible oil, its calorific value and cetane number are higher compared to many others. The Jatropha plant can grow almost anywhere, even on gravely, sandy and saline soils. Its water requirement is extremely low (Senthil Kumar et al., 2003).

1.1 Potential production of biofuels in Malaysia

To date, palm oil as a primary feedstock is being used to produce biodiesel in Malaysia. As a matter of fact, the thriving plantation of palm oil is the main factor which drives Malaysia towards developing biodiesel production and technology. Different from other countries such as U.S. which mainly utilizes soybean oil while Europe utilizes rapeseed oil, biodiesel produced in Malaysia from palm oil offers several distinct advantages. It requires less manual power for harvesting. A hectare of oil palm can produce approximately five tonnes of palm oil, compared with other vegetable oils like rapeseed and soybean, which can produce one tonne and 375 kg each (Lim and Teong, 2010).

Palm oil is the main agricultural product of Malaysia, accounting for about 73% of the total agricultural output. It is the world's second largest producer, accounting for 42.3% of worldwide production and 48.3% of the world's total exports of palm oil (Zhou and Thomson, 2009). Therefore, Malaysia proved to be a leading producer of palm oil in the world with 17.7 million tonnes produced in 2008 (Abdullah et al., 2009). The global land area of mature oil palm increased from 3.5Mha in 1975 to 13.1Mha in 2005. Most of this increase is found in Malaysia (increasing from 0.4 to 3.6 Mha) and in Indonesia (increasing from 0.1 to 3.9 Mha) (Wicke et al., 2010).

Since 1980s, Malaysian Palm Oil Board (MPOB) in collaboration with the local oil giant ‘‘Petronas’’ has begun transesterification of crude palm oil into palm biodiesel (Kalam and Masjuki, 2008). Being the world's largest producer and exporter of palm oil, it was imperative that Malaysia emerged as one of the pioneers in the palm biodiesel industry. This was achieved through the aggressive stance by Malaysian Palm Oil Board (MPOB) when the project of developing palm biodiesel was initiated at laboratory scale. Laboratory testing, stationary engine evaluation and field trials had been carried out successfully on a large number of diesel-powered vehicles including taxis, commercial trucks, passenger cars and buses (Lim and Teong, 2010).

The Malaysian Government has been researching the use of a B5 (5% processed palm oil and 95% diesel) blend for vehicles and industrial sectors (Zhou and Thomson, 2009). As Malaysia’s biodiesel production is mainly palm oil based though it has taken some initiative to introduce jatropha production in mass level. Jatropha is also getting importance for a yield factor of 1.2 tons/ha with about 0.8 kg/m^2 production of seeds per year. Jatropha is a potential second generation biodiesel feedstock, though it still requires more research and development (Jayed et al., 2009). Jatropha is a tropical plant that can be grown in areas of low or high rainfall. Inedible oil can be extracted from the seed, with properties similar to those of palm oil (Thornley et al., 2009).

2. EXPERIMENTAL SET UP AND TEST PLAN

Figure 1 shows the test rig set up for the experimental study. It consists of a test-bed, a diesel engine, a dynamometer, a fuel tank, an operation panel, exhaust emission analyzers, etc. A one-cylinder, four-stroke diesel engine is selected for the study and is mounted on a test-bed. It is a water-cooled, direct injection diesel engine. Its major specifications are shown in Table 1. The engine is coupled to an eddy current dynamometer. It can be operated at a maximum power of 20 kW at 2450 to 10000 rpm. Specific fuel consumption, exhaust gas temperature and the exhaust emissions of neat diesel (D100) fuel and blend of jatopha oil and palm diesel with diesel fuel (J5P5) were masured at different brake mean effective pressure conditions. The engine speed was set at 2000 rpm. The major properties for both fuel samples are available in Table 2. Two exhaust gas analyzers named Bacharach and Bosch gas analyzers were used to analyze the exhaust emissions from the engine, i.e, carbon monoxide, carbon dioxide, hydrocarbon, smoke and oxides of nitrogen.

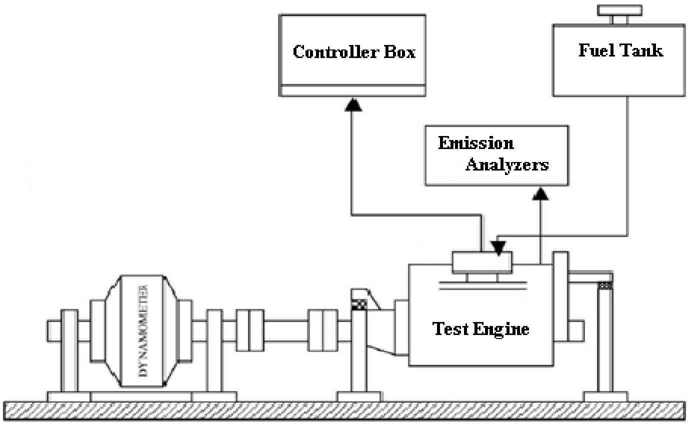

Figure1. Schematic diagram of the engine test rig.

Table 1. Specifications of the test engine.

Engine type		4 – stroke DI diesel engine
Number of cylinders		One
Aspiration		Natural aspiration
Cylinder bore x stroke	*mm*	92 x 96
Displacement	*L*	0.638
Continuous rated output	*rpm*	2400
	kW	7.7
At 1 – hr rated output	*rpm*	2400
	kW	8.8
Power take – off position		Flywheel side
Cooling system		Radiator cooling

Table 2. Fuel properties.

Fuel sample	*Viscosity at 40°C (cSt)*	*Viscosity at 100°C (cSt)*	*Density (g/ml)*	*Cloud Point (°C)*	*Pour Point (°C)*	*Heating value (MJ/kg)*
D100	3.602	1.486	0.8305	14-16	12	46.40
J5P5	4.922	1.819	0.8346	16	12	45.35

3. RESULTS AND DISCUSSION

3.1 Brake specific fuel consumption (BSFC)

The variation in BSFC values with load for D100 and J5P5 fuels is presented in Figure 2. It shows that BSFC values decrease with the increase in load. It can be seen from the figure that in case of P5J5, the BSFC values were determined to be higher than those of neat diesel fuel (D100). This trend was observed owing to be fact that P5J5 has a lower heating value than does D100 and thus more P5J5 fuel was required for the maintenance of a constant power out put. Within the range of tests, the total BSFC values of P5J5 fuel are higher (4.9%) than that of D100 fuel.

CO forms during the combustion process with rich air–fuel mixtures regions and when there is an insufficient oxygen to fully burn all the carbon in the fuel to CO_2. The Figure 3 shows the comparison of the CO emissions of D100 and J5P5 different fuel samples at different brake mean effective pressure conditions. It can be seen that CO for J5P5 is less than D100 over the entire range of load. In total around 48% of CO emissions decreases compared to D100. The reason for decreasing exhaust emissions from J5P5 is the presence of oxygen in it.

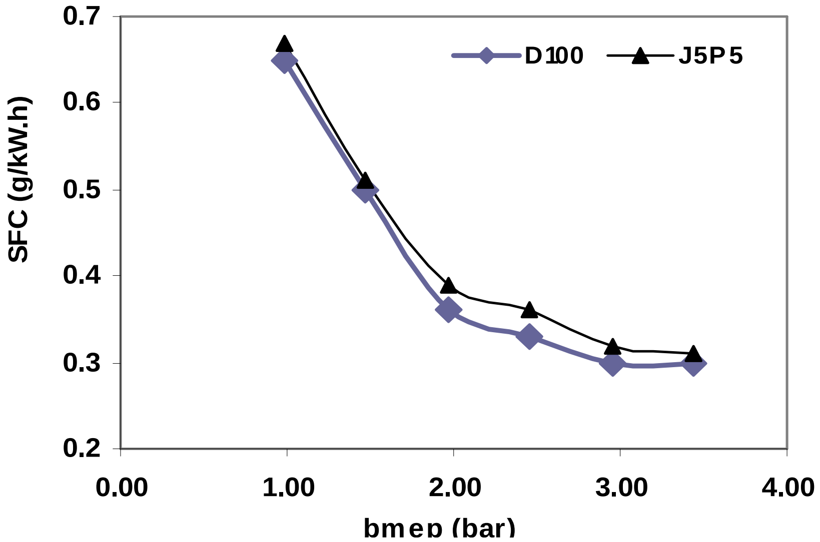

Figure 2. Varition of BSFC with bmep.

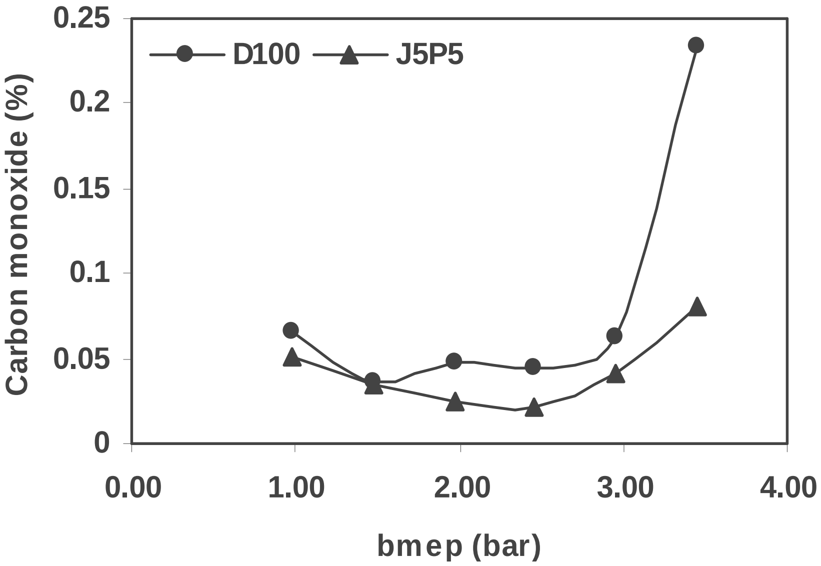

Figure 3. Varition of CO emission with bmep.

3.2 Carbon monoxide (CO) emission

The oxygen in the J5P5 helps to reduce exhaust emission including CO and smoke emissions, while this may provide excess oxygen to produce higher NO_x emission. It can be observed that mostly the CO initially decreased with load and later increased till end of the loading for both the fuels.

Initially, at low load conditions cylinder temperatures might be low, which increased with loading due to more fuel injected inside the cylinder. At elevated temperature, performance of the engine improved with relatively better burning of the fuel resulting in decreased CO. However, on further loading, it might be observed that the excess fuel required led to formation of more smoke, which might have prevented oxidation of CO into CO_2, consequently increasing the CO emissions.

3.3 Carbon dioxide (CO2) emission

Figure 4 compares the CO_2 emissions of D100 and P5J5 fuel samples used in the diesel engine. Overall, there was not much difference found throughout the range of the load in the both fuel samples. The CO_2 emissions for both fuels increase with increases in load, as expected. In the range of whole engine load, the CO_2 emissions of diesel fuel are higher than that of the J5P5 fuel. This is because the J5P5 fuel contains oxygen element; the carbon content is relatively lower in the same volume of fuel consumed at the same engine load, consequently the CO_2 emissions from the J5P5 fuel are lower. Around 6.7% CO_2 is decreased comapred to D100 over the entire range of load. It should be mentioned here that the formation of CO_2 is an exothermic reaction. Therefore, it supports the higher value of exhaust gas temperature of D100 fuel compared to J5P5 fuel.

3.4 Hydrocarbon (HC) emission

The variation of HC emissions for D100 and P5J5 fuel samples are shown in Figure 5.

P5J5 generally exhibit lower HC emission at lower engine loads and higher HC emission at higher engine load compared to D100. This is due to relatively less oxygen avaialble for reaction when more fuel is injected into the engine cylinder at higher engine load. However, around 7.3% HC emission was decreased comapred to D100 over the entire range of load.

3.5 Smoke emission

Figure 6 compares the variation of smoke emission with respect to brake mean effective pressure for the engine using D100 and J5P5 fuels. The smoke emission for J5P5 is generally lower than that of D100. The reason for lower smoke density for J5P5 may be better combustion of fuel due to oxygen atom present in it, which enhanced its complete burning as compared to D100. In toal around 8% smoke was decreased comapred to D100 over the entire range of load. It can also be seen from Figure 6 that smoke level increased sharply with increase in load for both fuels tested. It was mainly due to the decreased air–fuel ratio at such higher loads when larger quantities of fuel are injected in to the combustion chamber, much of which goes unburnt into the exhaust.

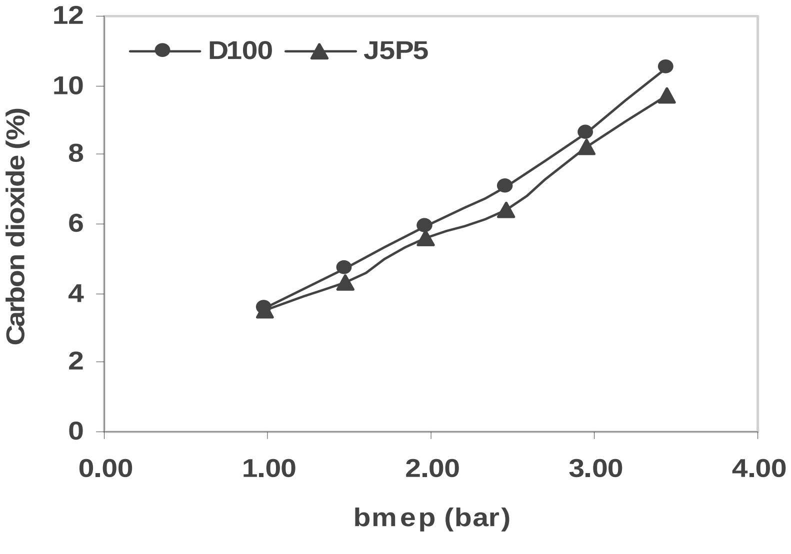

Figure 4. Variation of CO_2 emission with bmep.

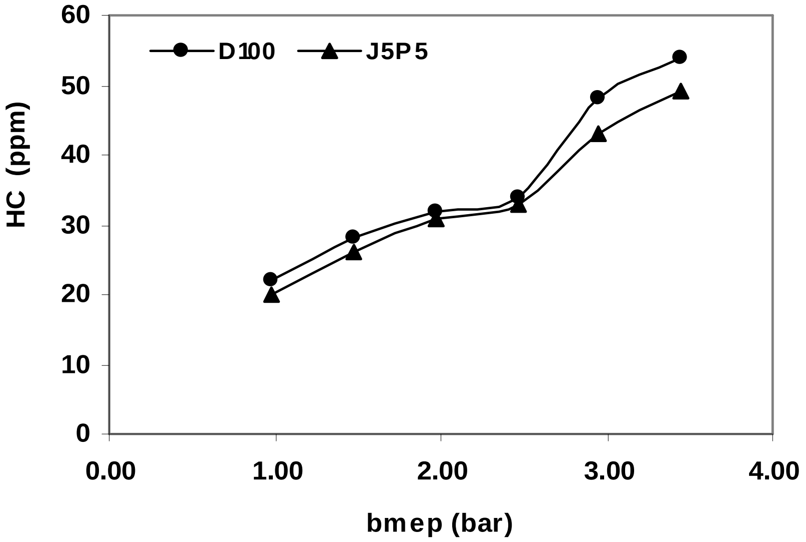

Figure 5. Variation of HC emission with bmep.

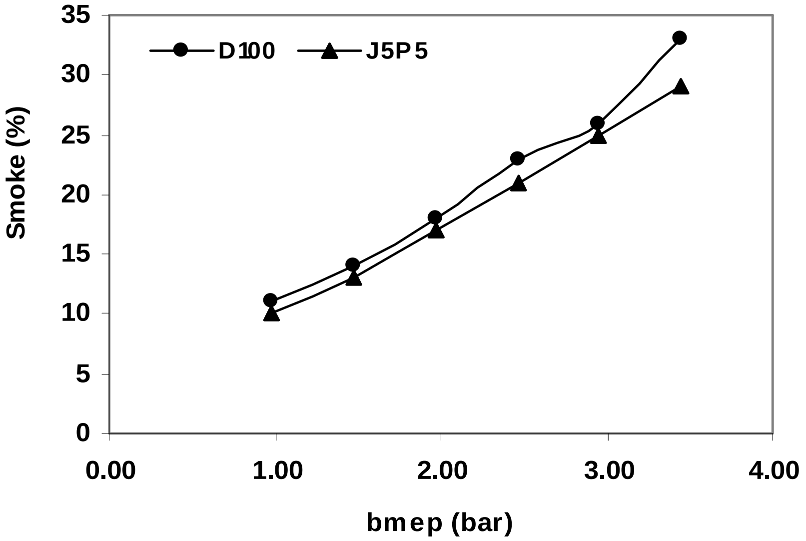

Figure 6. Variation of smoke emission with bmep.

3.6 Oxides of nitrogen (NOx) emission

The NO_x values as parts per million (ppm) for D100 and J5P5 in exhaust emissions are plotted as a function of brake mean effective pressure in Figure 7.

NO_x is produced during the combustion process when nitrogen and oxygen are present at elevated temperature. Generally, there was not much difference found in both fuel samples within the experimental range. From Figure 7, it can be seen that within the range of tests, the total NO_x emissions from the P5J5 are little bit higher (5%) than that of diesel fuel. The reason is possibly due to some presence of oxygen in P5J5.

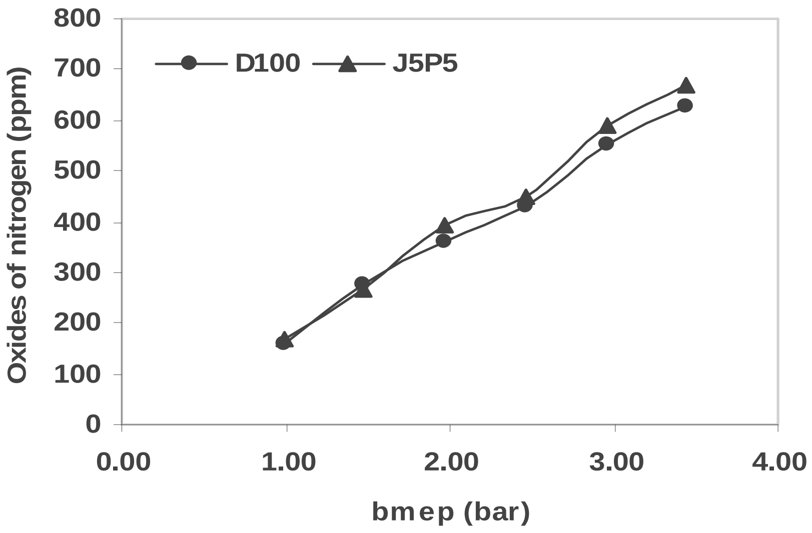

Figure 7. Variation of NOx emission with bmep.

3.7 Exhaust gas temperature (EGT)

Figure 8 shows the variation of exhaust gas temperature with brake mean effective pressure for D100 and J5P5. Generally, the trend of EGT increases with the increase in engine loading for the both fuel samples tested.

The increase in exhaust gas temperature with load is obvious from the simple fact that more amount of fuel was required in the engine to generate that extra power needed to take up the additional loading. The burning of D100 fuel was found to have the highest exhaust gas temperature value. This may be attributed due to its higher heating value compared to J5P5 fuel.

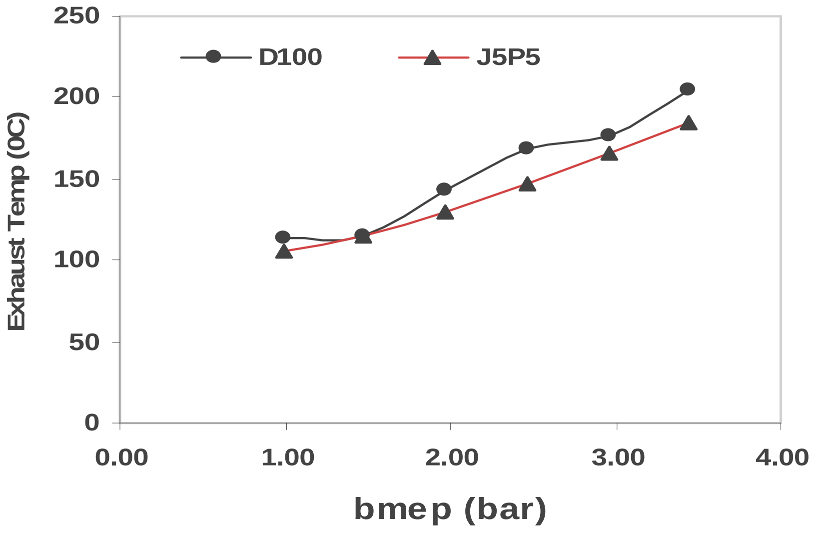

Figure 8. Variation of EGT with bmep.

4. CONCLUSIONS

Main objective of present investigation is to evaluate suitability of J5P5 as an extended fuel for diesel engine and to evaluate specific fuel consumption, exhaust gas temperature and the emission charateristics of the engine. Engine test results show that as over all the emissions of CO, CO_2, HC, smoke and also exhaust gas tepeerature are found to be lower than that of diesel fuel (D100). However some NO_x emissions and brake specfic fuel combustion were increased compared to D100 fuel.

Finally, the present analysis revealed that J5P5 fuel is fund to be quite suitable as an alternative to petroleum diesel without ant engine modification.

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