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# Optimization of Injection Timing and Pressure of Stationary C.I. Engine Operated on Pre-Heated Karanj-Diesel Blend

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## Abstract

Property changes associated with differences in chemical structure between vegetable oil and petroleum-based diesel fuel may ask for change in the engine operating parameters such as injection timing, injection pressure etc. These operating parameter changes can cause difference in performance and exhaust emissions than the optimized settings chosen by the engine manufacturer. In the present work, an experimental set was developed to investigate the effect of injection timing and injection pressure in Kirloskar AV1 diesel engine operated on heated Karanj-Diesel blend.

A fuel preheater was designed to preheat the Karanj-Diesel blend using waste heat of exhaust gas. The preheater could provide temperature within a range of 55-65 °C. A blend of 40% Karanj oil and 60% Diesel was finalized for our study because at the so available temperature range, a viscosity of B40 could match the viscosity of Diesel. Experiments were performed at different injection pressures from 170 to 200 bar and injection timings from 23° to 15° BTDC. From the analyses of performance parameter such as brake specific fuel consumption and brake thermal efficiency, optimum fuel injection timing and injection pressure were determined.

## 1. Introduction

Energy demand is increasing due to ever increasing number of vehicles employing internal combustion engines. Also, world is presently confronted with the twin crisis of fossil fuel depletion and environmental degradation. Fossil fuels are limited resources; hence, search for renewable fuels is becoming more and more prominent for ensuring energy security and environmental protection [1]. Besides them, some other aspects such as increasing fuel price, the idea of supplying fuel demand from local sources, lessening the import of crude oil and creating new employments have been promoting these investigations [2]. For the developing countries of the world, fuels of bio-origin can provide a feasible solution to the crisis.

When Rudolf Diesel invented the diesel engine more than a century ago, he demonstrated the principle of compression ignition in the engine by employing peanut oil as fuel and suggested that vegetable oils would be the future fuel for diesel engines. However, petroleum was discovered later, which replaced vegetable oils as engine fuel due to its abundant supply. Thus, it is highly desired in present context to direct research towards renewable fuels of bio-origin, which are environment friendly, provide improved performance, and are not harmful to human health [1]. The impact is further promoted by the fact that the calorific value, heat of vaporization, and stoichiometric air/fuel ratio and Cetane number of the non-edible oils in their pure form are comparable to diesel oil [3, 4]. However, the impediments are their high viscosity.

India and many other countries of the world are producing a host of non-edible oils such as Linseed, Castor, Mahua, Rice Bran, Karanj (Pongamia Glabra), Neem (Azadirachta Indica), Palash (Butea Monosperma), Kusum (Schlelchera Trijuga), etc. Some of these oils are not yet being properly utilized, although it has been estimated that even some other plant-based and forest derived oils have a much higher production potential. These oils are also very economical comparable to edible oils, therefore it was decided to carry out experimentation on Karanj oil.

### 1.1: Karanj Oil

The botanical name of Karanj tree is Pongamia Pinnata. It is chiefly found along the banks of streams and rivers or near the seacoast but can be cultivated on any type of soil, and have low moisture demand. It resists drought well, is moderately frost hardy and is highly tolerant of salinity. The cultivation of these plants is easier and the plant has high oil content (25–30%) [5].

Tree starts bearing at the age of 4 - 7 years. The pods come to harvest at different periods of time in different parts of the country, but the harvest season extends in general from November - December to May - June. The yield of the seed is said to range from 9-90 kg per tree, indicating a yield potential of 900 to 9000 kg seed/ha (assuming 100 trees /ha). Nearly 25% of this yield might be safely considered as oil because the yield of oil from seeds is around 24 to 27.5%. The total yield in India is estimated to be about 135000 tons. But only 8000 tons of oil is presently being utilized which is only 6% of the total estimated produce. Thus there is an ample scope for utilizing the energy source (Karanj oil) as fuel [5].

Raheman and Phadatare have done experimentation on Karanj Methyl Ester and found that there was no significant change in engine performance when used as a fuel in conventional unmodified CI engine [6]. Since the cost of Transesterification is significant, it was decided to carry out experimentation using unmodified Karanj oil.

Kinematic viscosity of Karanj oil was found to be 10.7 times more than that of diesel determined at 40°C. It is reduced with increase in diesel amount in the blend and preheating the Karanj vegetable oil [7]. A similar reduction in specific gravity was also observed. However, the calorific value of biodiesel (K40) was found to be 36.12 MJ/kg, which is less than the calorific value of diesel (42.21 MJ/kg) and greater than that of the Karanj oil (34 MJ/kg). As the percentage of Karanj vegetable oil in the blends increased, the calorific value decreased. The flash points of Karanj oil and biodiesel were found to be greater than 100°C, which is safe for storage and handling [8].

## 2. Experimental Set-Up

A naturally aspirated direct injection diesel engine is more sensitive to fuel quality. The main problem of using Karanj oil in unmodified form in diesel engine is its high viscosity. Therefore, it was necessary to reduce the blend viscosity before injecting it in the engine. This was done by heating the blend using waste heat of exhaust gases and an optimum blend was finalized on the basis of temperature obtained by the fuel preheater.

A typical engine system widely used in the agricultural sector has been selected for present experimental investigations. A single cylinder, four stroke, constant speed, water cooled, direct injection diesel engine was procured for the experiments. The technical specifications of the engines are given in table 1.

**Table 1 Specifications of the Engine**

| S. No. | Component | Unit | Description |
|---|---|---|---|
| 1. | Name of the engine | - | Kirloskar Oil Engine **Model AV1** |
| 2. | Type of engine | - | Vertical, four stroke cycle, single acting, totally enclosed, high speed, C.I. engine |
| 3. | No. of cylinders | - | 1 |
| 4. | Direction of rotation | | Counter clockwise (When looking at flywheel) |
| 5. | IS Rating at 1500 rpm | kW(bhp) | 3.7 (5.0) |
| 6. | Bore | mm | 80 |
| 7. | Stroke | mm | 110 |
| 8. | Cubic Capacity | liters | 0.553 |
| 9. | Compression Ratio | - | 16.5 : 1 |
| 10. | No. of Injection Pumps and Type | - | 1 number, Single cylinder, flange mounted without camshaft |
| 11. | Governor type | - | Mechanical centrifugal type |
| 12. | Class of governing | - | B1 |

The engine operated at a constant speed of 1500 rpm. An electric dynamometer was coupled to the engine for loading. Figure 1 shows the typical layout of the experimental setup for the present investigation. The main components of the experimental setup are two fuel tanks (Diesel and Karanj oil), heat exchanger, exhaust gas line, and performance and emissions measurement equipment. The engine is started with diesel and once the engine warms up, it is switched over to Karanj oil. After concluding the tests with Karanj oil, the engine is again switched back to diesel before stopping the engine until the Karanj oil is purged from the fuel line, injection pump and injector in order to prevent deposits and cold starting problems. This purging typically takes about 15 min at idling. Hartridge smoke-meter was used to measure Smoke density.

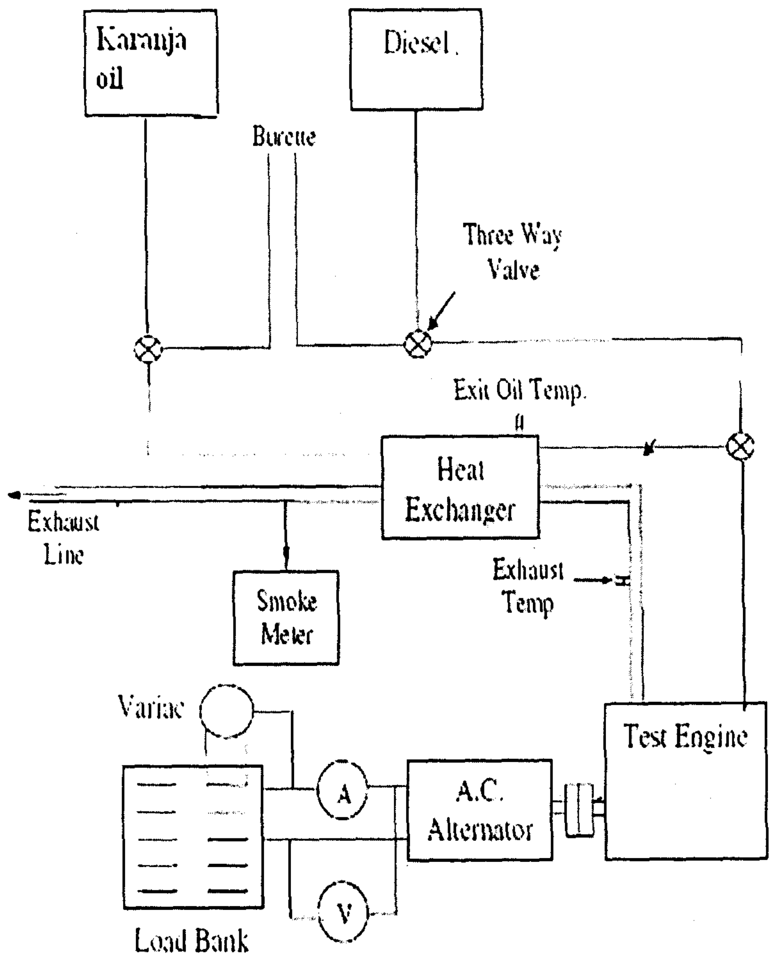


**Figure 1: Schematic Diagram of Experimental Set-up**

## 3. Results and Discussion

After finalizing Karanj oil as substitute fuel, attempts were made to reduce the viscosity of Karanj oil by preheating. Since the preheater could not raise the temperature sufficiently enough to bring down the viscosity close to that of Diesel, it was decided to carry out experimentation using Karanj-Diesel blend. As the temperature range was about 55-65 °C, it was decided to perform experimentation on a blend of 40% Karanj oil and 60% Diesel as in this temperature range the viscosity of the above blend matches with the viscosity of Diesel oil.

### 3.1 Effect of injection timing on brake specific fuel consumption

Injection Timing is a very important parameter that significantly influences all engine characteristics. This is mainly due to the fact that injection timing influences the mixing quality of the air-fuel mixture and, consequently, the combustion process, including harmful emission. Brake Specific Fuel Consumption is a comparative parameter that shows how efficiently an engine is converting fuel into work. This parameter is preferred, rather than thermal efficiency, because all quantities are measured in standard and accepted physical units: time, horsepower and mass.

Brake Specific Fuel Consumption (BSFC) has been plotted against load for various injection pressures at constant speed of 1500 rpm for different injection timings from 23° to 15° BTDC. Figures 2 - 6 show these plots for variation of BSFC with load at different injection pressures ranging from 170 to 200 bar at all injection timings under study. It is observed from these plots that with the reduction in injection advance from 23° to 19° BTDC, the injection pressure for minimum BSFC lies between 200 to 190 bar at all loads. On further reducing the injection advance from 19° to 15° BTDC, the injection pressure for minimum BSFC becomes 170 bar at all loads, and the lowest values of BSFC were observed for an injection timing of 17° BTDC at all loads.

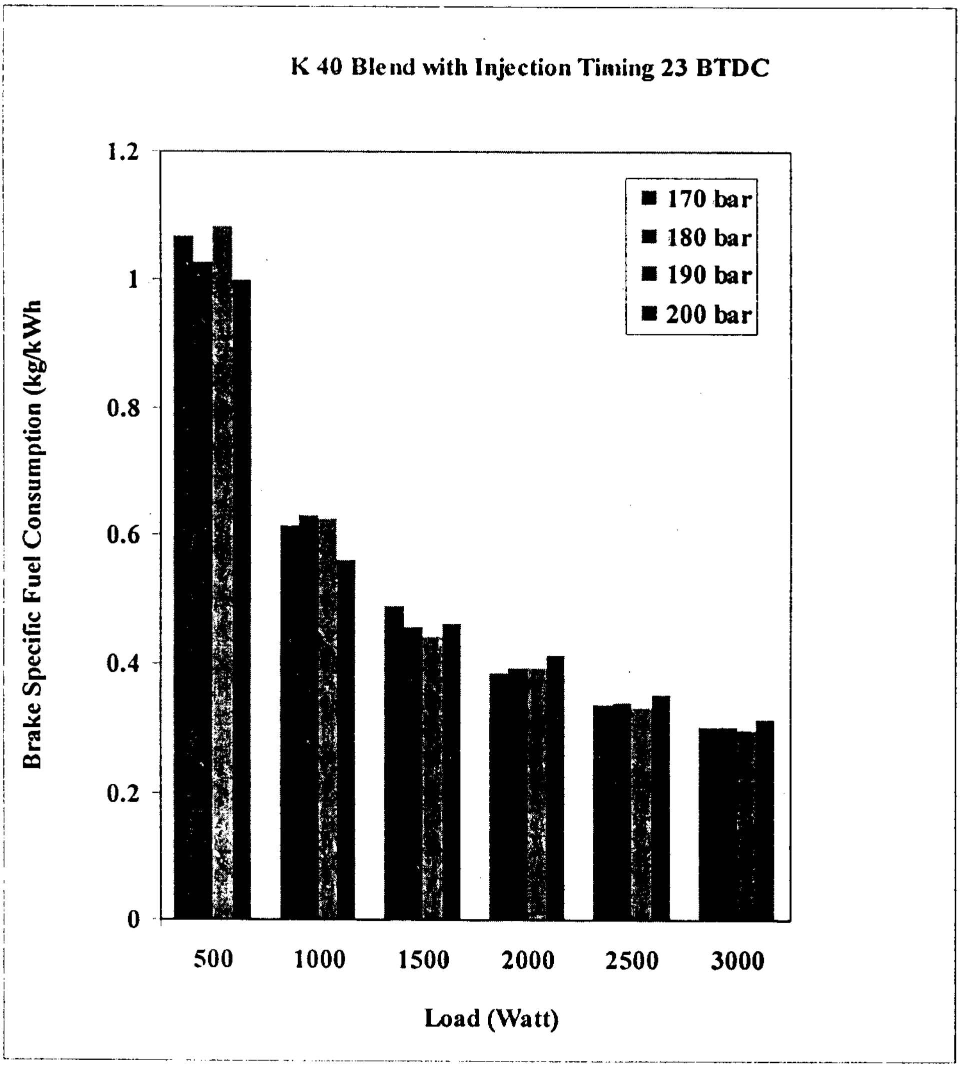


Figure 2: BSFC V/s Load at 23° BTDC

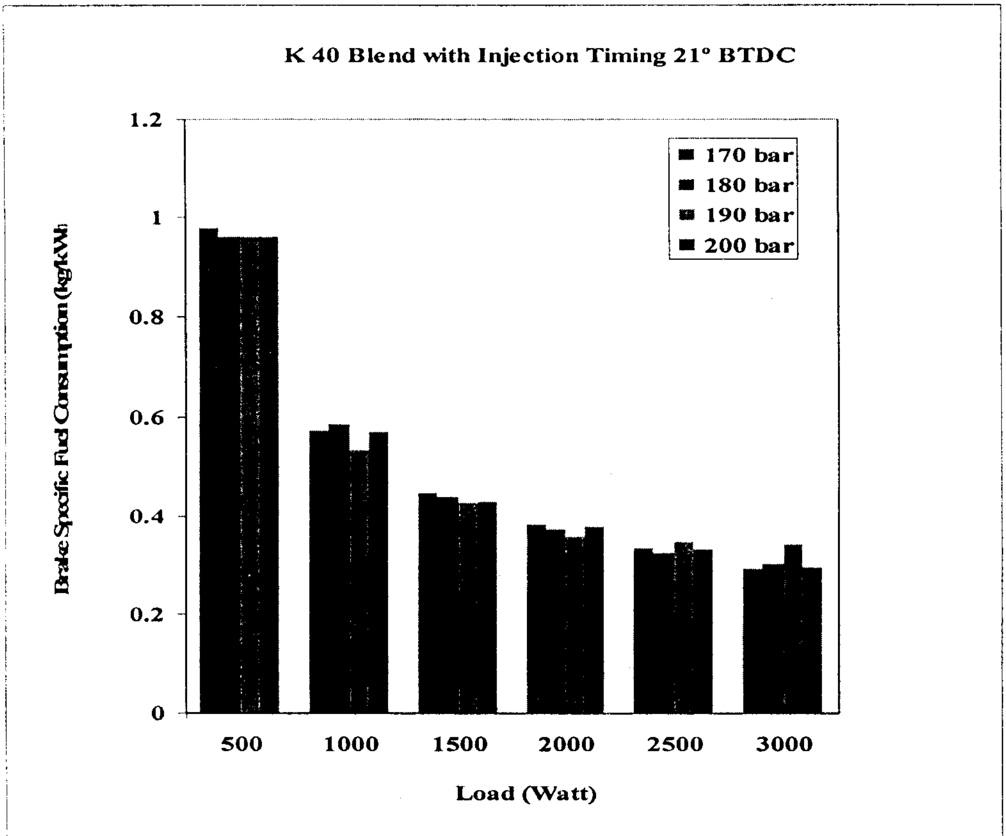


Figure 3: BSFC V/s Load at 21° BTDC

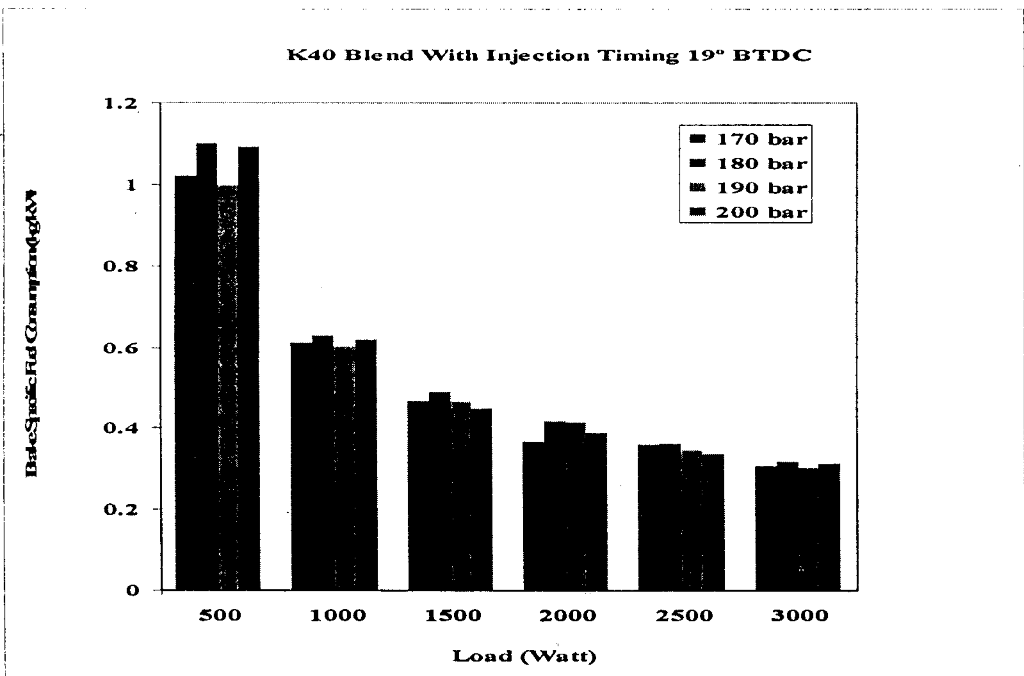


Figure 4: BSFC V/s Load at 19° BTDC

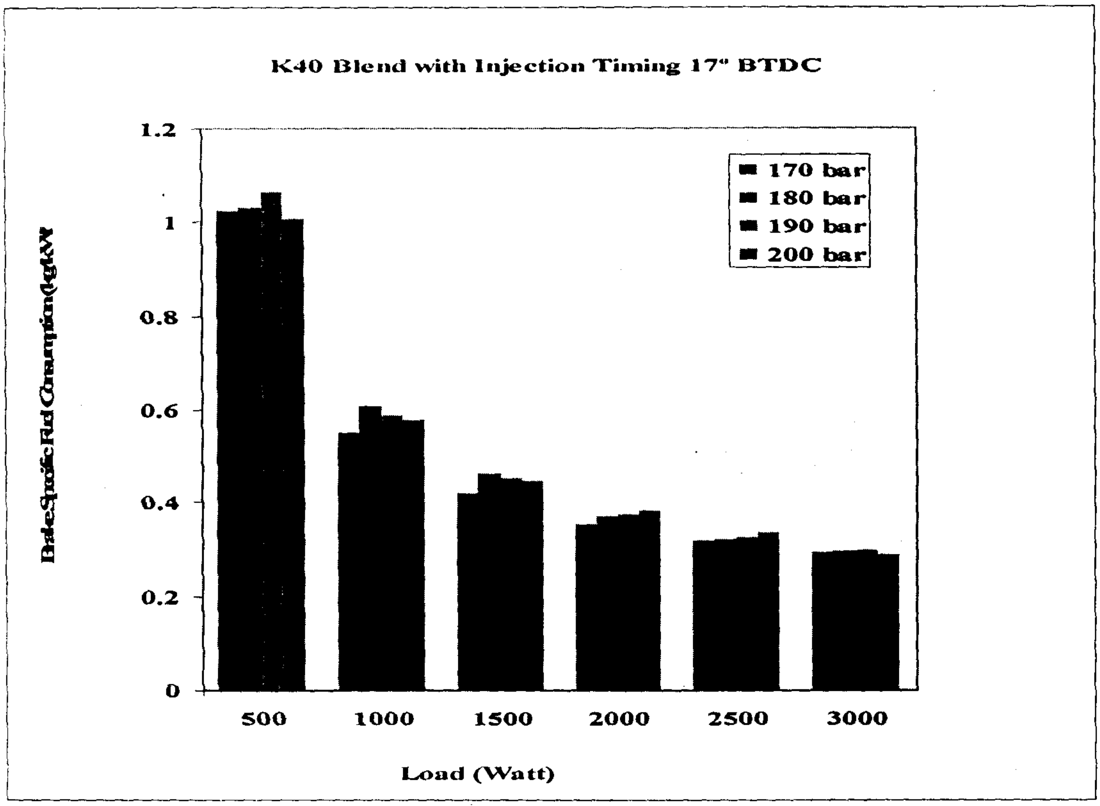


Figure 5: BSFC V/s Load at 17° BTDC

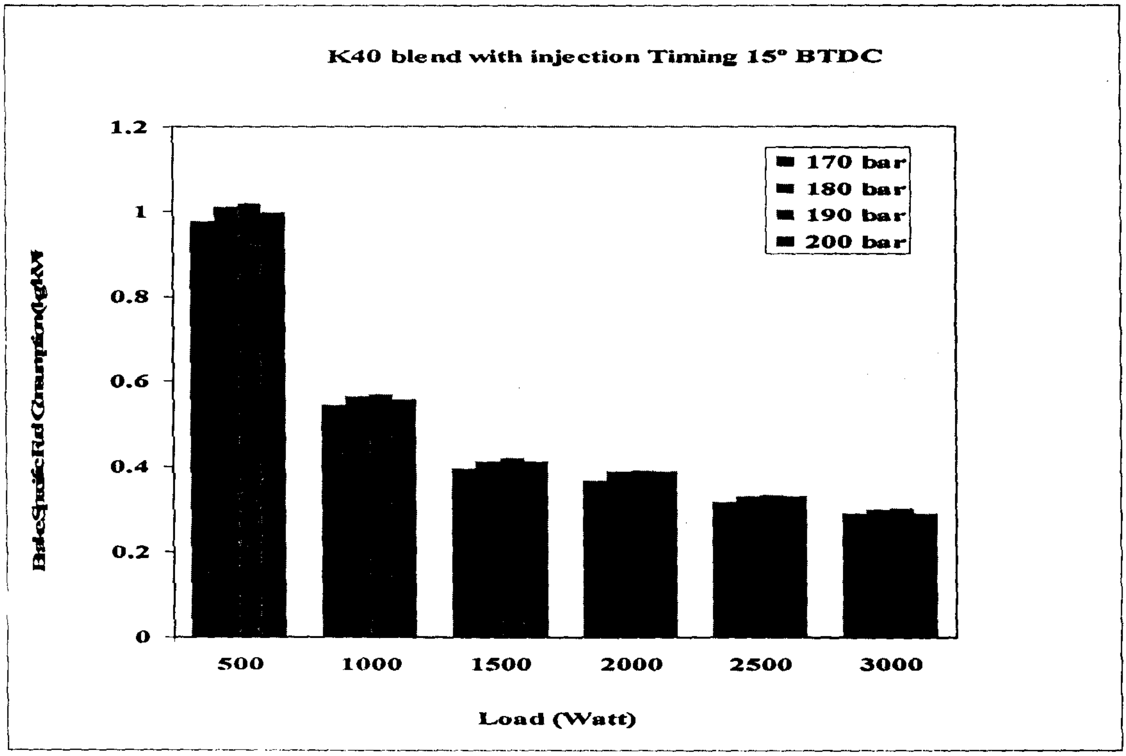


Figure 6: BSFC V/s Load at 15° BTDC

### 3.2 Effect of injection timing on brake thermal efficiency

Similar trends are observed for Brake Thermal Efficiency, when plotted against load. Figures 7-11 plotted for BTE v/s load at different injection timing and injection pressure show that brake thermal efficiency slightly increases by reducing injection timing from 23° to 17° BTDC, on further retarding BTE tends to decrease. Same pattern was observed for all injection pressures under study, but highest values were obtained at an injection pressure of 170 bar and an advance of 17°BTDC. This can be attributed to good fuel atomization and good mixing air-fuel supply. From these plots it was also observed that maximum value of BTE lay between 80-90 % of full load for all injection pressures under study. The maximum value of thermal efficiency at that injection pressure was 30.91 % for injection timing 17°BTDC. Reduction in brake thermal efficiency from 30.91 to 30.89 percent was observed over a change in injection timing from 17° to 15° BTDC.

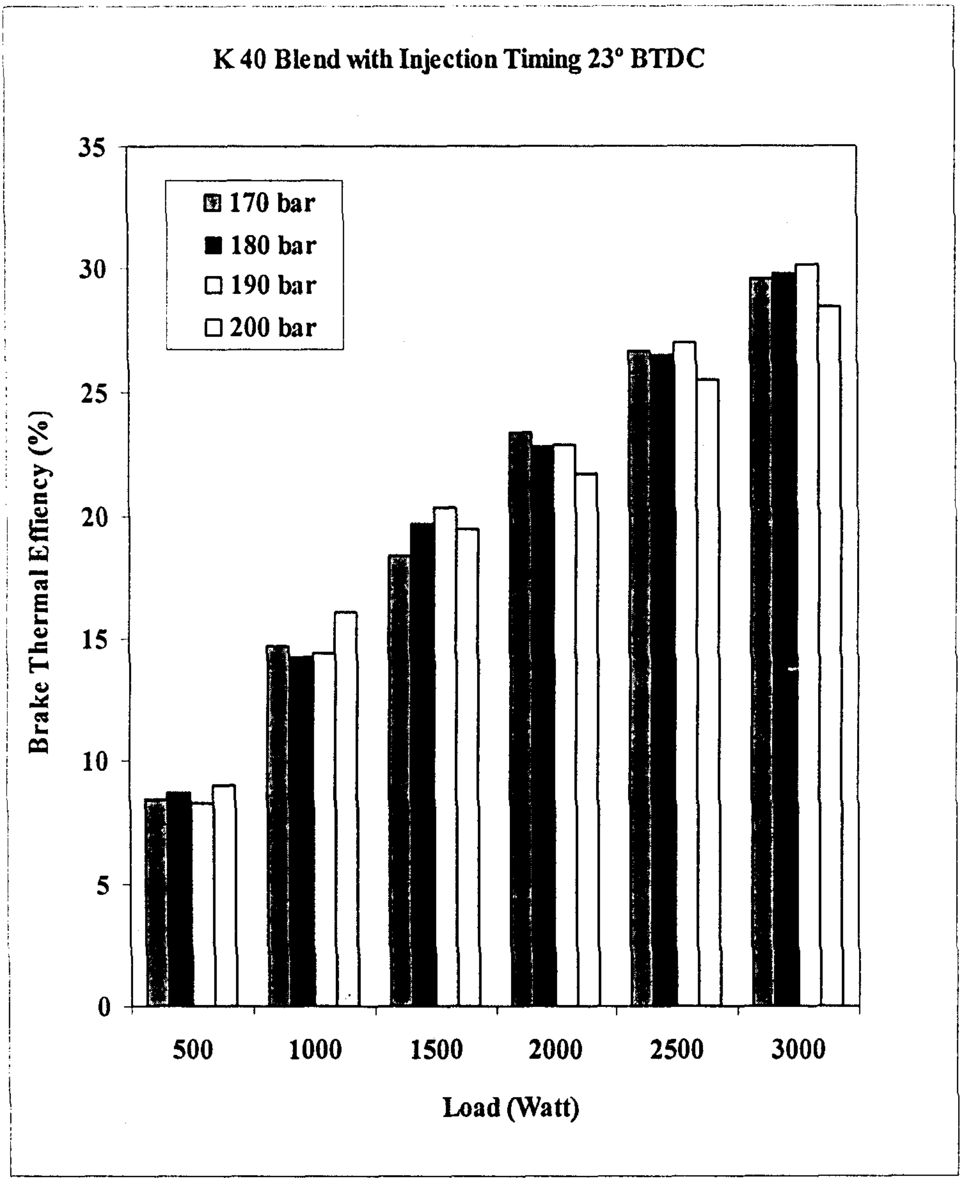


Figure 7: BTE V/s Load at 23° BTDC

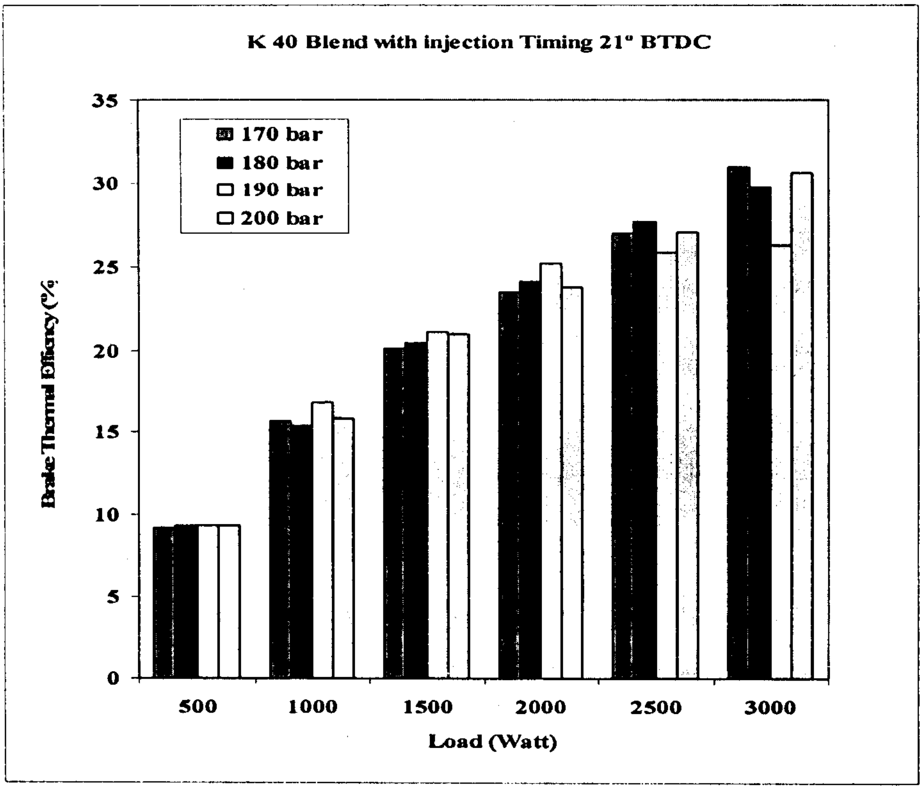


Figure 8: BTE V/s Load at 21° BTDC

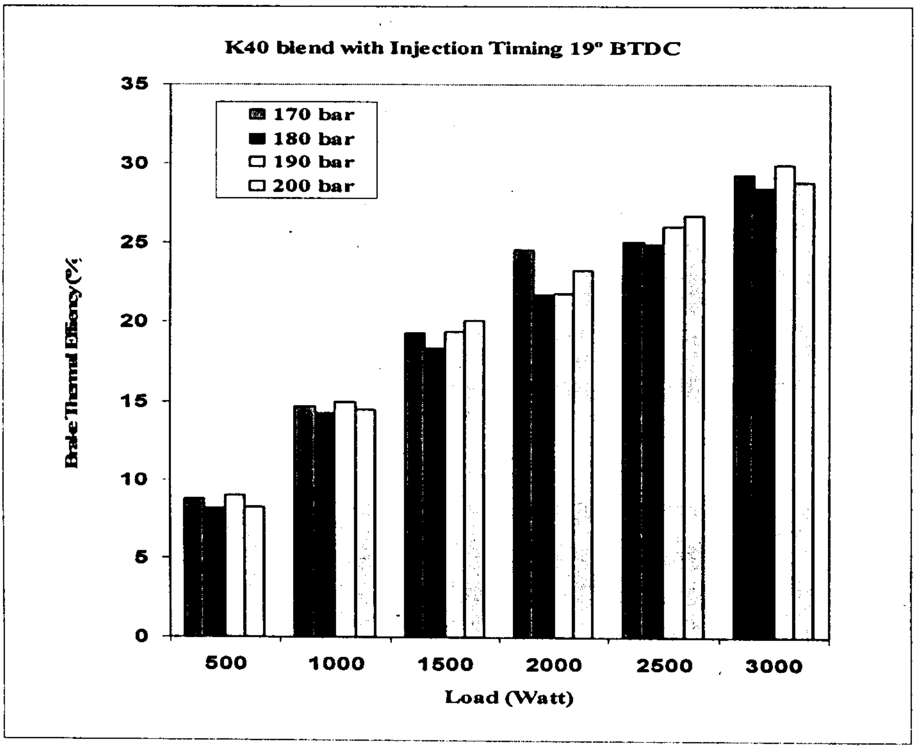


Figure 9: BTE V/s Load at 19° BTDC

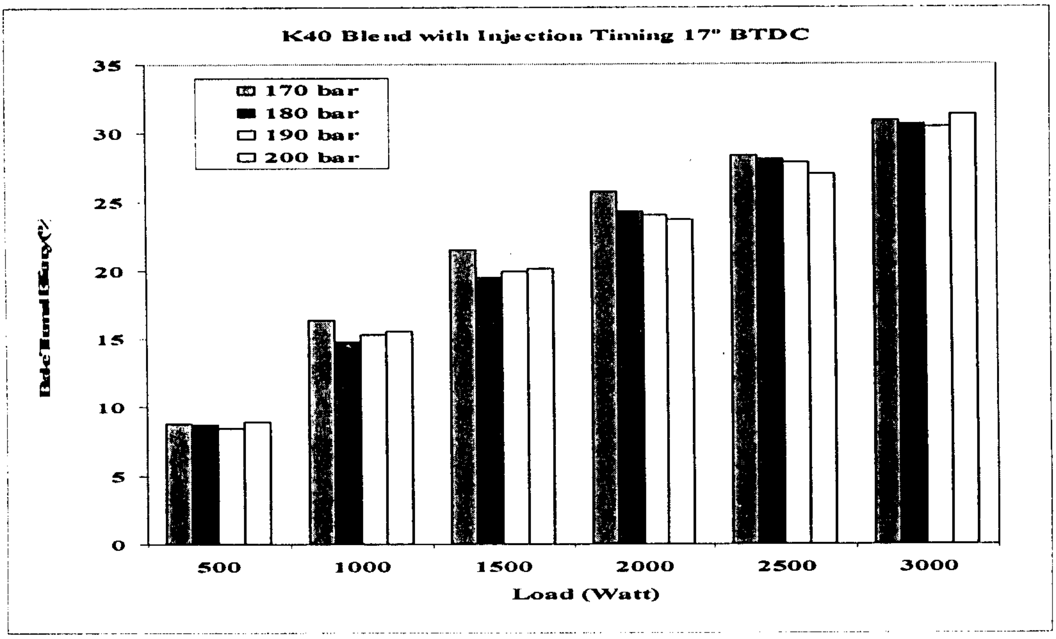


Figure 10: BTE V/s Load at 17° BTDC

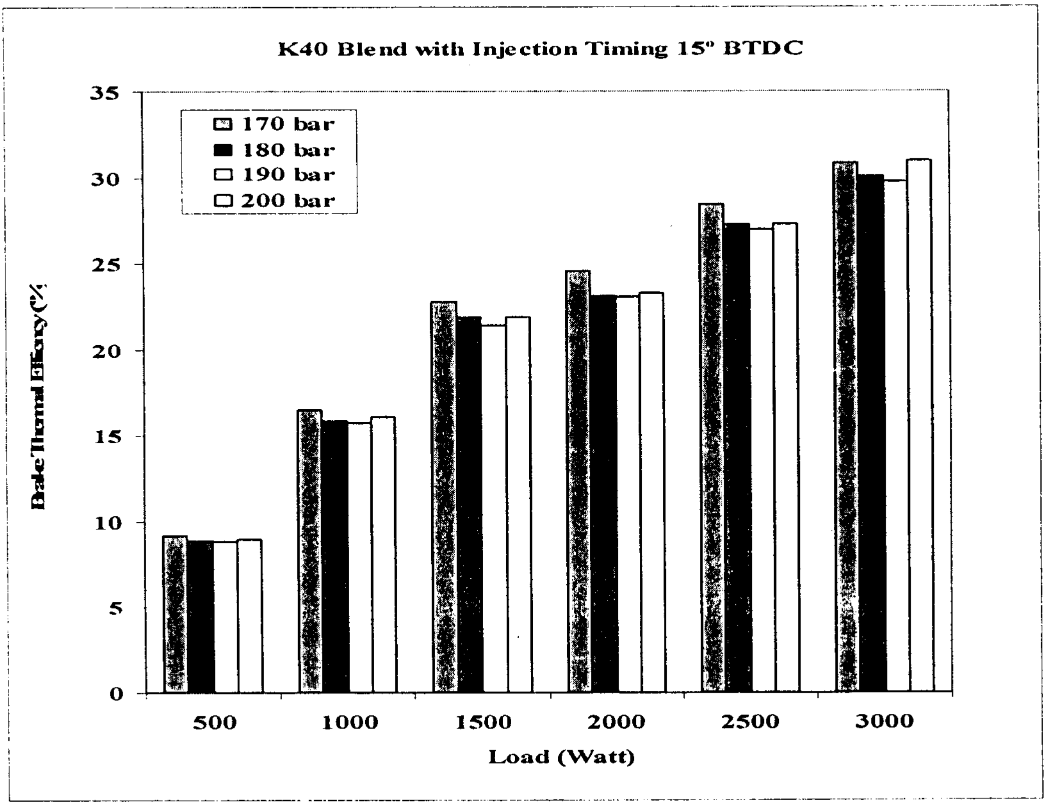


Figure 11: BTE V/s Load at 15° BTDC

### 3.3 Smoke emission and exhaust temperature

Smoke is produced during acceleration, overloading or even during full load operation of the engine. Smoke density for Karanj-Diesel blend was greater than that of diesel (Figure 12). This is possibly a result of poor spray atomization and non-uniform mixture formation with Karanj oil. Smoke density increases from 18 HSU to 52 HSU with increase in load in case of diesel oil while smoke density increases from 32 HSU to 68 HSU with increase in load in case of preheated Karanj-Diesel blend. From the experimentally measured smoke density for different injection pressure and injection timing, it is observed that effect of injection timing and injection pressure on smoke is not very significant.

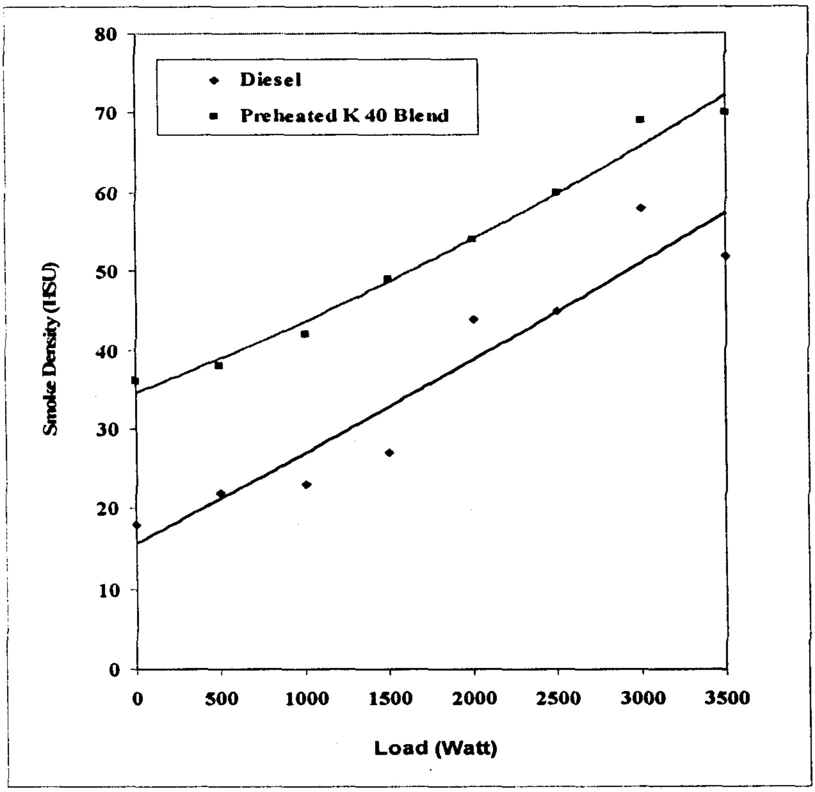


**Fig. 12: Smoke (HSU) V/s Load at 17° BTDC**

Exhaust gas temperature that indicates the cylinder temperature, was measured under all experimental conditions. It was seen from the plots that exhaust gas temperature increases with load, although exhaust gas temperature for Karanj-Diesel blend was less than exhaust gas temperature for Diesel through out the load range for all injection pressures under study. At increased load conditions, increased generation of heat is due to heat transfer being less for Karanj Oil than for Diesel although the time available was the same (constant speed engine), resulting in increased exhaust gas temperature.

## 4. Conclusion

On the basis of the observations and the results of the experimental investigations on a single cylinder, four strokes, constant RPM, stationary, water cooled, compression ignition engine, run on Karanj - Diesel blend and Diesel oil at different injection pressure and injection timing, the following conclusions may be drawn from the present study:

1. Preheating of the Karanj - Diesel blend can be done by utilizing the fuel pre-heater of the exhaust gases from the engine. With the help of pre-heater, the temperature of Karanj – Diesel blend could be raised to 50-65 °C throughout the operating range of load.
2. It was found that substitution of Diesel oil by Karanj oil to the extent of 40% was best possible in the temperature range of 55-65 °C, as at this proportion the viscosity of the blend becomes equal to that of pure Diesel.
3. A successful operation of a compression ignition engine, fuelled with Karanj -Diesel blends over a wide range of load, injection pressures and injection timing without causing any undesirable combustion phenomena, was observed.
4. There was significant effect of injection timing on engine performance. For the above blend (K-40), the injection timing of 17° BTDC was found to be the optimum injection timing, as the highest brake thermal efficiency and the lowest brake specific fuel consumption were observed over the entire load range at this injection timing.
5. There was significant effect of injection pressure on engine performance. For the blend (K-40), the injection pressure of 170 bar was found to be the optimum injection pressure, as the highest brake thermal efficiency and the lowest brake specific fuel consumption were observed over the entire load range at this injection pressure.
6. Smoke is formed as a result of thermal cracking of molecules at elevated temperatures. Slightly higher smoke emissions were observed with blend (K-40) over the entire load range mainly due to poor atomization of Karanj oil. Effect of different injection timing and injection pressure on smoke is not very significant.

## 5. References


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