STUDIES ON EFFECT OF INJECTION PRESSURE AND INJECTION TIMING ON PERFORMANCE AND EMISSIONS OF A 4S SINGLE CYLINDER DIESEL ENGINE FUELLED WITH SPENT COFFEE POWDER BIODIESEL BLENDS

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INTRODUCTION: In recent decades there is a significant rise in coffee production and consumption, and consequently an increase in the coffee waste generation. Spent coffee powder has no commercial value and is currently disposed of as a solid waste or in some cases used as fertilizer. Due to high organic material content and the presence of compounds such as caffeine, tannins and polyphenols which can have negative effects on the environment and result in the release of greenhouse gases in to the atmosphere. Thus the disposal of spent coffee powder should be properly managed. As per the preliminary experiments conducted spent coffee powder consists of 18% oil content in it, which can be converted to biodiesel by the method of transesterification.

It is well known that injection timing and pressure play the most important role in determining engine performance, especially in pollutant emissions. Decrease in injection pressure results in inferior combustion which leads to increase in BSFC and decrease in BTE. Increase in Injection pressure results in better mixing of air and fuel. As a result, combustion improves which leads to reduced BSFC and increased BTE. Due to superior air–fuel mixture resulting from increase in injection pressure, CO and HC emission decreases. Also, exhaust gas temperature decreases too. Increase in injection pressure results in increased heat release rate which leads increase in NOx emission.

The diesel engine principle demands self-ignition of the fuel as it is injected at some degrees before top dead Centre (btddc) into the hot compressed cylinder gas. Longer delays between injection lead to unacceptable rates of pressure rise with the result of diesel. Alternative fuels have been noted to exhibit longer delay periods and slower burning rate especially at low load operating conditions hence resulting in late combustion in the expansion stroke. Advanced injection timing is expected to compensate these effects.

OBJECTIVES:

- To extract oil from Spent Coffee Powder using solvent extraction method.
- To produce biofuel from the obtained oil by the method of transesterification.
- To blend the produced Biofuel with Diesel in various proportions (B10, B20, B30, etc.)
- To find out the properties of various blends (B0, B10, B20, B30, B40 etc.) like Specific gravity, Flash point, Fire point, Viscosity, Calorific value etc.,
- To test the produced biodiesel and its blends in a Diesel engine.
- To study the Performance and emissions of the engine at various injection pressures (180 bar, 200bar and 220 bar) and various injection timings (19°, 23° and 27° bTDC).

3. METHODOLOGY

(i) Extraction of oil: The oil is extracted from spent coffee powder by Soxhlet extraction method. In Soxhlet extraction the sample (spent coffee powder) is wrapped in a porous cellulose paper and it is placed in an extraction chamber, which is suspended above a flask containing the solvent (methanol/ethanol). The flask is heated and the solvent evaporates and moves up into the condenser where it is converted into a liquid that trickles into the extraction chamber containing the sample. The extraction chamber is designed so that when the solvent surrounding the sample exceeds a certain level it overflows and trickles back down into the boiling flask. At the end of the extraction process, which lasts a few hours, the flask containing the solvent and shell extract is removed. Finally the solvent in the flask is distilled to get the required oil.

(ii) Production of Biodiesel: The Free Fatty Acid (FFA) content of the produced oil is determined by titrating the oil against NaOH solution using iso propyl alcohol with phenolphthalein indicator. If the FFA content is lesser than 2% single stage alkali base process is chosen and if the FFA content is greater than 2% acid base and alkali base process is chosen.

- Acid catalyzed transesterification
  This is the first stage of transesterification; it reduces the FFA content present in the oil in the presence of concentrated sulphuric acid, as a catalyst and methanol/ethanol as a reactant. The mixture of catalyst, reactant and oil is heated in a flask with constant stirring at 60°C for 2 hours, and then it is taken out and allowed to settle for 3 hours in a separating flask. Here the FFA’s are separated and it is to be removed from the oil.
- Base catalyzed transesterification
  The settled lower layer of the earlier stages having low FFA is used as a raw material for this stage. The product of earlier stages i.e. pure triglycerides is made to react with methanol and suitable quantity of catalyst NaOH for 1ltr of oil
and is heated to 60°C with constant stirring for 2 hours. The reacted product of this second stage is made to settle down under gravity. The lower layer containing the glycerol and other impurities, are separated from the methyl esters and the upper layer is distilled to recover methanol and remaining biodiesel is washed and heated to around 100°C to remove the moisture content.

(iii) Characterization and Performance tests: The biodiesel produced is blended with diesel in various proportions (B0, B10, B20, B30, etc.). The properties of the produced fuel like Specific gravity, Flash point, Fire point, Viscosity, Calorific value etc., are determined and compared to that of diesel. The produced biofuel blends are tested in a diesel engine to ascertain performance and emission characteristics by varying Injection Pressure and Injection timing.

Spent coffee powder  Soxhlet Extractor  Distillation  Pensky Martens Apparatus  Viscometer

Hydrometer  Bomb Calorimeter  Dynamometer  Engine  Smoke meter

4. RESULTS AND DISCUSSIONS:
   (i) COMPARISON WITH ASTM STANDARDS

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Properties</th>
<th>Standard</th>
<th>Range</th>
<th>Obtained</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Flash point (°C)</td>
<td>ASTM D93</td>
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<td>135</td>
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<tr>
<td>2</td>
<td>Kinematic Viscosity (Cst) at 40°C</td>
<td>ASTM D445</td>
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<td>3</td>
<td>Specific gravity</td>
<td>ASTM D4052</td>
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<td>0.875</td>
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<td>4</td>
<td>Calorific value (MJ/kg)</td>
<td>ASTM D240</td>
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<tr>
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<td>Ash, %/w/w</td>
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<td>0.5max</td>
<td>NIL</td>
</tr>
<tr>
<td>6</td>
<td>Carbon residue, Ramsbottom, %/w/w</td>
<td>IS:1448 (P 8)</td>
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</tr>
</tbody>
</table>

American Society for Testing and Materials (ASTM) is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. The obtained fuel properties are compared with ASTM standards and it is found that all the values are within specified range.
(ii) Engine Performance Analysis

![BRAKE THERMAL EFFICIENCY v/s LOAD](image1)

![BSFC v/s LOAD](image2)

(iii) Emissions

![CARBON MONOXIDE v/s LOAD](image3)

![HC v/s LOAD](image4)

![NOx v/s LOAD](image5)

CONCLUSIONS

- The measured properties of produced methyl ester (kinematic viscosity, flash point, fire point) met the ASTM D6751 biodiesel standards.
- Spent coffee biodiesel can be used as an alternative fuels in existing diesel engine without modification of basic engine.
- It is observed that the brake thermal efficiency of B20 and B30 blends are marginally higher when compared with that of diesel.
- NOx emissions of biodiesel and its blends are marginally higher than that of neat diesel. At maximum loading B20 and B30 blends are having approximately 6% higher NOx compared to neat diesel. With respect to injection pressure, increasing the injection pressure led to increased NOx emissions. By retarding the injection timing by 4 degrees NOx emissions drastically reduced by 26%, whereas advancing the injection timing by 4 degrees resulted in increase of NOx emissions by 29 % at full load.
- HC emissions of spent coffee biodiesel blends are lower than neat diesel fuel. It can be concluded the HC emission decreases with increase in percentage of biofuels in the blend. Increasing the injection pressure led to decreased HC emissions. By retarding the injection timing reduced HC emissions increased by 16%, whereas advancing the injection timing by 4 degrees (23° btdc to 27° btdc) resulted in decrease of HC emissions by 29.5% at full load.
- CO emission of biodiesel and its blends is competitively lesser to diesel. B30 shows lower CO emission compared to neat diesel at all loads. Increased injection pressure led to decreased CO emissions. Advancing the injection timing led to reduced CO emissions.
SCOPE FOR FUTURE WORK

- The performance and emission characteristics of the engine with variation of compression ratio of the engine can be studied for all blends.
- Experimentation can be carried out on multi cylinder engines to study the behaviour of these fuels to ascertain the usage in the practical engines.
- Performance and emission tests with biodiesel blends can be carried out in an adiabatic engine. Approximately one third of the heat released by the combustion of the diesel engine is dissipated to the cooling medium. If this can be reduced by thermally insulating the piston crown, cylinder liner and cylinder head, the gases in cylinder will become much hotter and hence more work can be extracted from them. This is the concept of adiabatic engine, which will improve the performance of the engine and emissions may be reduced.
- Along with biodiesel blends some oxygenated fuel additives can be added and Performance characteristics can be analyzed.
- Preheated fuel can be used in order to get the reduction in viscosity which will result in similar characteristics to that of diesel. The heat energy required for preheating of fuel can be obtained by utilizing the heat of exhaust gases.