5.1 INTRODUCTION

Most of the alternative fuels identified today are proved to be a partial substitute for the existing one due to their few undesirable fuel characteristics. The biofuel turpentine also has few insufficient fuel properties, which is not permitting the complete replacement of diesel fuel. However, modifications on fuel admission methods change the utilization of turpentine in large magnitude. Therefore, three methods of fuel admission such as bi-fuel, dual fuel and sole fuel methods have been tried in this work to apply large fraction of turpentine in a regular DI diesel engine. This chapter details the methodology of various fuel admission techniques experimented in this work.

5.2 BI-FUEL METHOD [Method: 01]

Bi-fueling or blending is the simplest technique for admitting low cetane fuels in CI engines. According to this method turpentine is mixed with standard diesel oil in various proportions on volume basis and its properties such as calorific value and viscosity were evaluated before admission.

Table 5.1 details the various blend compositions prepared for investigation and its properties.
Table 5.1 Blend composition and its properties

<table>
<thead>
<tr>
<th>S. No</th>
<th>Blends</th>
<th>Calorific value kJ/kg</th>
<th>Viscosity cSt</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diesel baseline</td>
<td>42,700</td>
<td>3.7</td>
</tr>
<tr>
<td>2</td>
<td>10T(10% turpentine 90% diesel)</td>
<td>42,880</td>
<td>3.6</td>
</tr>
<tr>
<td>3</td>
<td>20T(20% turpentine 80% diesel)</td>
<td>43,040</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>30T(30% turpentine 70% diesel)</td>
<td>43,200</td>
<td>3.3</td>
</tr>
<tr>
<td>5</td>
<td>40T(40% turpentine 60% diesel)</td>
<td>43,380</td>
<td>3.1</td>
</tr>
<tr>
<td>6</td>
<td>50T(50% turpentine 50% diesel)</td>
<td>43,550</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Among the prepared blends, the low turpentine blends such as 10T (10% Turpentine 90% diesel) and 20T (20% Turpentine 80% diesel) were not considered for experimentation as these blends are not providing higher diesel replacement. The prepared blends other than 10T and 20T were tested under various combinations of engine parameters to obtain optimum blend and engine parameters. This experiment involves three parameters such as injection timing, injection pressure and blends composition. Hence, a method called ‘Taguchi Method of Optimisation’ was tried in this work to optimise the above parameters in lesser number of trials.

5.2.1 Taguchi Method of Optimisation

Usually, alternative fuels are tested in the existing engines that use petrol or diesel as fuel. These engines are specially designed for petro fuels and also optimised for it. Therefore, the performance provided by the engine may not be optimum for the new kind of fuel used in it. Hence, the engine parameters such as compression ratio, injection pressure, injection timing etc. needs to be modified for the new kind of fuel to obtain maximum performance and low emission.
As the engine setup chosen for experimentation is a constant speed engine, the two engine parameters such as injection pressure and injection timing are considered for optimisation in association with the blend composition.

These three factors or parameters are tested at three levels and each one has two degrees of freedom (Table 6.2). The suitable experimental layout for these parameters at three levels and two degrees of freedom is \( L_9 \) orthogonal array (Table 6.4). It has four columns and nine rows. The parameters such as injection timing, injection pressure and blend proportions are arranged in column 1, 2 and 4. Column 3 is used for the error of the experiment.

According to this layout, nine experiments were conducted and the test trials were selected at random, to avoid systematic error creeping into the experimental procedure. During each trial the response parameters such as brake thermal efficiency, \( \text{NO}_x \), smoke and Ignition delay were observed. However, only brake thermal efficiency was considered for the calculation of signal to noise ratio because the optimization is based on maximum brake thermal efficiency.

Usually, Taguchi method of optimisation uses a parameter called signal to noise ratio (S/N) for measuring the quality characteristics. This optimisation is used the-higher-the-better kind of S/N ratio as this optimisation is based on higher BTE.

This work used software called ‘Minitab Release 15’ for designing Taguchi method. The optimum level of the parameters involved in the experiments were obtained from the tables and response graphs.

After identification of optimum level of parameters a full range of experiments were conducted using the selected blend at optimum engine
setting and then compared with the standard diesel operation. An ANOVA was also performed for the involved parameters to identify its percentage contribution over the desired response.

5.2.2 Regression Equations

Using the results of Taguchi experiments, the regression equations are generated for the various output parameters with the help of ‘Datafit’ regression software. To validate the regression equations an experiment was also conducted using the parameter levels that were not used for generation of regression equation.

5.3 DUAL FUEL METHOD [Method: 02]

From the literature it is found that this method permits more diesel replacement than the bi-fuel method and hence it is tested as a second method. In this method, the primary fuel (turpentine) was inducted through intake manifold and the pilot fuel (diesel) was injected through regular fuel injection device.

The literatures also show that the quantity of inducted fuel affects the engine performance comparatively higher. Therefore the quantity of primary fuel (turpentine energy share) that gives maximum performance has been identified initially and used for the rest of the experiment. The performance and emission parameters obtained at this energy share were used for comparison with standard diesel operation.

5.4 SOLE FUEL METHOD [Method: 03]

This technique permits 100% diesel replacement using turpentine after little engine modification. The factors that prevent turpentine direct injection in CI engine are its low cetane number and high self-ignition
temperature. To overcome this, the in-cylinder temperature of the engine must be maintained well above the self-ignition temperature of turpentine. This can be provided by an air preheater housed in the suction side of the engine. Hence, the air enters the engine with high temperature and its temperature is increased further by adiabatic compression, which is sufficient to auto-ignite the injected turpentine.

In this experiment, as the intake temperature decides the performance of engine it is optimised first. Then the performance and emission characteristics of the engine obtained at optimum heater energy share were used for comparison with standard diesel operation.