Chapter 5

Analysis of Experimental Results
5.1 LIQUID PRODUCT PROPERTIES

Rice Husk Pyrolysis liquid has been tested in Environmental science and Chemistry Laboratory of BIT, Durg. The liquid has a higher heating value of about 20 kJ/kg as produced with about 25%, wt. water that cannot be separated. The liquid is referred as 'bio-oil'. Moreover it is found that properties of the bio-oil depends upon the operating parameters of the process. There are some important features of this liquid that should be emphasized which are described below and the main properties are typed in Table 20.

"BIO OIL"
Table 20 - Properties of Rice Husk derived Bio-oil

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTY</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>20-25%</td>
</tr>
<tr>
<td>pH</td>
<td>2.5 - 3.8</td>
</tr>
<tr>
<td>Density</td>
<td>1 - 1.2 g/cc</td>
</tr>
<tr>
<td>Flash Point</td>
<td>50°C - 60°C</td>
</tr>
<tr>
<td>HHV</td>
<td>17 - 20 MJ/kg</td>
</tr>
<tr>
<td>Viscosity</td>
<td>8 - 10cP at 40°C</td>
</tr>
<tr>
<td>Conductivity</td>
<td>8.38 mS</td>
</tr>
<tr>
<td>Elemental Analysis C</td>
<td>58.5 - 62%</td>
</tr>
<tr>
<td>H</td>
<td>5.3 - 7%</td>
</tr>
<tr>
<td>N</td>
<td>0.2 - 0.3%</td>
</tr>
<tr>
<td>S</td>
<td>.05%</td>
</tr>
<tr>
<td>O (By Difference)</td>
<td>35.9 - 30.9%</td>
</tr>
</tbody>
</table>

**Water**

Water is miscible with bio-oil up to around 20-25%. The water is produced in the Pyrolysis reaction together with any water contained in the feed to the liquid product. The amount of water in the product also depends on the process parameters. Water is important in many ways – increasing water usually reduces viscosity and heating value.

**pH**

pH value of bio-oil varies from 2.5 to 3.8. The degradation products from cellulose include organic acids such as formic and acetic acids which give the bio-oil its low pH.

**Density**

The density of Pyrolysis liquid is very high at around 1.2 g/cc.
**HHV**

The heating value of bio-oil is about 17-20 MJ/kg, which is about half of the fuel oil. This means that 2 kg of bio-oil is required for the same energy input as 1 kg fossil fuel oil.

**Viscosity**

The viscosity of bio-oil varies between 8 to 10 CP at 40°C. The viscosity is a function of water content, process parameters, feed stock and storage conditions.

**Solids**

The bio oil contains solids contents i.e. char of around 1 to 2%. This char may have deleterious effects on applications. This may be removed by liquid filtration.

**Flash point**

The flash point of the samples of bio oil varies between 50°C to 60°C. Good oil should not volatilize under the working temperature. From this point of view the study of flash point of a oil is of great significance for industrial application.

### 5.2 YIELD OF OIL

The experiment shows that yield of liquid, which varies from 11% to 40% is the function of final temperature, particle size and heating rates. The effects of these three parameters on yield of oil have been analyzed in the following manner.

(i) Effect Of Final Pyrolysis Temperature & Heating Rates Of Different Particle Size.
(ii) Effect of Heating Rates and different particle sizes for final Pyrolysis temperature.

(iii) Effect of Final Temperature & Particle Sizes for different Heating Rates

Although all the three parameters tend to affect the yield, the general trends indicates that final temperature and particle size having the marginal effect on the yield of liquid but heating rate has the predominance on it.

The figure 5.1 to 5.5 shows the following trends:-

i) The general trends indicate marginal effect of final temperature on yield of liquid between 400 to 550°C for all particle sizes, the yield decreases when final Pyrolysis temperature is increased beyond 550°C.

ii) It is clearly shown by experiments that increase in heating rates has the maximum effect on increase of yield for all particle sizes.

iii) For particle sizes between 0.8 mm and 3mm, the peak oil yield appears to be at 500°C for heating rates up to 1.4 kW and 550°C for heating rates above 1.4 kW.

iv) For particle sizes of less than 0.3 mm the peak oil yield is shown to be for final temperature between 450 and 500°C for various heating rates.
5.2.1 EFFECT OF FINAL PYROLYSIS TEMPERATURE & HEATING RATES OF DIFFERENT PARTICLE SIZE.

Effect of Particle Size

Particle Size - 3 mm Size

Fig. 5.1 Effect of Final Temperature & Heating Rate for the particle Size of 3mm
Fig. 5.2 Effect of Final Temperature & Heating Rate for the particle Size of 2.5 mm
Fig. 5.3 Effect of Final Temperature & Heating Rate for the particle Size of 0.8 mm
Particle Size - 0.3 mm Size

Fig. 5.4 Effect of Final Temperature & Heating Rate for the particle Size of 0.3 mm
Particle Size - 0.01 mm Size

Fig. 5.5 Effect of Final Temperature & Heating Rate for the particle Size of 0.01 mm
The figure 5.6 to 5.10 shows the following trends:-

(i) The general trends indicate marginal effect of particle size on yield of liquid between 3mm to 0.3 mm for all final temperatures, the yield decreases when particle size decreases beyond 0.3 mm.

(ii) It is clearly shown by experiments that increase in heating rate has the maximum rate has the maximum effect on increase of yield for all the final temperatures.

(iii) Final temperature between 500°C and 550°C, the peak oil yield is shown to be for particle size of 0.3 mm for various heat rates.

(iv) Final temperature of 550°C above, the oil yield decreases for all particle sizes and various heat rates.
5.2.2. Effect of Heating Rates and different particle sizes for final Pyrolysis temperature.

At Temperature 400°C

Fig. 5.6 Effect of Heating Rates & Particle size for final temperature 400°C
Fig. 5.7 Effect of Heating Rates & Particle size for final temperature 450°C
Fig. 5.8 Effect of Heating Rates & Particle size for final temperature 500°C
Fig. 5.9 Effect of Heating Rates & Particle size for final temperature 550°C
Al 600°C

Fig. 5.10 Effect of Heating Rates & Particle size for final temperature 600°C
The figure 5.11 to 5.20 shows the following trends:

(i) The general trend indicates the strong effect of heating rates on yield of liquid for all particle sizes and at various temperatures.

(ii) It is clearly shown by experiments that decrease in particle size has marginal effect on increase of yield for all heating rates.

(iii) For fines (0.01 mm), the decrease in yield of liquid for all final temperatures and at various heat rates.

(iv) As the heating rates increases, the yield of liquid increases for all particle sizes and at various temperatures. This is due to the short residence time to achieve the final temperature which prevent the secondary Pyrolysis reaction inside the reactor.
5.2.3 Effect of Final Temperature & Particle Sizes for different Heating Rates

Fig. 5.11 Effect of Particle Size & Final Temperatures for Heating Rate of 1 kW
Fig. 5.12 Effect of Particle Size & Final Temperatures for Heating Rate of 1.1 kW
Fig. 5.13 Effect of Particle Size & Final Temperatures for Heating Rate of 1.2 kW
Fig. 5.14 Effect of Particle Size & Final Temperatures for Heating Rate of 1.3 kW
Fig. 5.15 Effect of Particle Size & Final Temperatures for Heating Rate of 1.4 kW
Fig. 5.16 Effect of Particle Size & Final Temperatures for Heating Rate of 1.5 kW
Fig. 5.17 Effect of Particle Size & Final Temperatures for Heating Rate of 1.6 kW
Fig. 5.18 Effect of Particle Size & Final Temperatures for Heating Rate of 1.7 kW
Fig. 5.19 Effect of Particle Size & Final Temperatures for Heating Rate of 1.8 kW
Fig. 5.20 Effect of Particle Size & Final Temperatures for Heating Rate of 2 kW