CHAPTER 10

AUTOGASIFICATION OF COIR PITH PELLET BY NON-ISOTHERMAL HEATING

10.1 INTRODUCTION

Thermal degradation of coir pith pellets is influenced by mode of heating. In Chapter 8, the influence of isothermal heating on thermal degradation of coir pith pellets has been evaluated. In non-isothermal heating, the coir pith pellet is subjected to gradual heating. The furnace temperature increases gradually heating the pellets. The surface temperature of the pellet increases rising the temperature along the radius of pellet. This non-uniformity in temperature leads to drying, devolatilization and gasification taking place simultaneously. Therefore the weight losses obtained at any time will be the combined loss.

10.2 MATERIAL

Coir pith pellets of 25 mm diameter and 25 mm long were prepared by using a die in a compression-testing machine. Sufficient number of pieces has been prepared and was kept in a double lined polythene bags.

10.3 EXPERIMENTAL SET-UP

A muffle furnace (160 × 150 × 300 mm) has been used in this study. A temperature controller was used to maintain desired rate of heating of 5 degree Celsius per minute. 10 samples of coir pith pellets similar in size have been placed on separate steel cups. The cups when placed into the
furnace will not touch the wall of the furnace. Each piece was weighed accurately.

10.4 EXPERIMENTAL PROCEDURE

After placing the samples the muffle furnace was switched ON. At a regular interval of every 5 minutes, a sample is taken out, cooled in a decicator and weighed. The experiment was continued till the surface temperature reaches 525°C. The experiment was repeated 3 times and the average weight was taken for further calculation.

10.5 EXPERIMENTAL RESULTS

Table A6.1 gives the experimental data. Figure 10.1 depicts the weight fraction yet to be converted at various times. It is observed that complete gasification of coir pith pellet takes place. The curve is divided into three zones. Temperature ranges for the three zones and its kinetic parameters are given in Table 10.1. Arrhenius plot for the three different zones are given in Figure 10.2.

Figure 10.1 Weight Fractions yet to be Converted at Non-Isothermal Heating
Table 10.1  Temperature Ranges and Kinetic Parameters in Different Zones

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Zones</th>
<th>Temperature Range (°C)</th>
<th>Activation Energy E (J / mole)</th>
<th>Frequency factor A (min⁻¹)</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I</td>
<td>27 to 125</td>
<td>1147.19</td>
<td>55.81</td>
<td>0.9921</td>
</tr>
<tr>
<td>2</td>
<td>II</td>
<td>125 to 425</td>
<td>11654.04</td>
<td>1.59</td>
<td>0.9008</td>
</tr>
<tr>
<td>3</td>
<td>III</td>
<td>425 to 525</td>
<td>27334.69</td>
<td>5.23</td>
<td>0.9901</td>
</tr>
</tbody>
</table>

Figure 10.2  Arrhenius Plot for the Different Zones

10.6  ANALYSIS OF DATA

Data on weight fractions yet to be converted (w) at every 5 minutes has been interpolated for every minute. Average temperature \( \bar{T} \) has been determined using the procedure outlined in Section 9.5. The rate of degradation (-rd) has been calculated by taking difference between subsequent
weight fractions yet to be converted. The average weight fractions yet to be converted are obtained by averaging subsequent weight fractions yet to be converted.

\[-rd = \frac{w_{(t-1)} - w_t}{\Delta t}\]  \hspace{1cm} (10.1)

\[w_{Av} = \frac{w_{(t-1)} + w_t}{2}\]  \hspace{1cm} (10.2)

The order of the reaction was assumed to be one (Williams and Besler 1993, 1996) and the reaction rate constant, \(k\) was calculated using

\[k = \frac{-rd}{w_{Av}}\]  \hspace{1cm} (10.3)

Tables A6.2 to A6.4 give the values of average temperature (\(\bar{T}\)), average weight (\(w_{Av}\)), rate (-\(rd\)) and rate constant (\(k\)) for every minute for the different zones respectively.

### 10.7 EFFECT OF AVERAGE TEMPERATURE (\(\bar{T}\)) ON RATE CONSTANT (K)

Since chemical reaction with heat transfer controls the overall reaction, the effect of average temperature (\(\bar{T}\)) on rate constant (\(k\)) was obtained by fitting the data. Figure 10.3 depicts the effect of average temperature on rate constant at non-isothermal heating temperature. The following equation is found to fit the data satisfactorily.

For zone – 1 \( k = 1 \times 10^{-5T} + 0.0109 \)  \hspace{1cm} (10.4)

For zone – 2 \( k = 0.0127 e^{0.0049T} \)  \hspace{1cm} (10.5)

For Zone – 3 \( k = 0.0004\bar{T} - 0.1285 \)  \hspace{1cm} (10.6)
Figure 10.3 Effect of Average Temperature on Rate Constant at Non- Isothermal Heating

10.8 EVALUATION OF MODELS

Equations (9.1), (10.4), (10.5) and (10.6) were verified by calculating weight fraction yet to be converted and comparing with experimental weight fraction yet to be converted.

The following calculation procedure was adopted:

1. Thermal diffusivity ($\alpha$) was calculated using Equation (9.1) for every minute.

2. From thermal diffusivity ($\alpha$), Fourier number ($N_{FO}$) was calculated using Equation (7.5).

3. Average temperature ($\bar{T}$) was calculated for each Fourier number ($N_{FO}$) and non isothermal - heating temperature ($T_s$) using Equation (7.4) for every minute.
4. The first order rate constant (k) can be determined for each average temperature ($\bar{T}$) using Equations (10.4), (10.5) and (10.6) for different zones respectively.

5. Weight fractions yet to be converted can be calculated for every minute. Using

$$w_t = w_{(t-1)} \left\{ \frac{(1-k/2)/(1+k/2)} \right\}$$

(10.7)

where, $w_t$ and $w_{(t-1)}$ are weight fractions yet to be converted at time (t) and (t-1) respectively.

6. The weight fractions yet to be converted thus calculated were compared with experimental weight fractions yet to be converted Figure 10.4 compare the results satisfactorily within ± 3%

![Figure 10.4 Comparison of Calculated and Experimental Weight Fraction at Non-Isothermal Heating](image-url)
10.9 CONCLUSION

Similar to the isothermal heating, a procedure has been proposed to evaluate the thermal diffusivity, average temperature and rate constant for every minute. Using the rate constant, the weight fraction of pellet yet to be converted has been calculated for every minute and compared satisfactorily with experimental results.