8.1 INTRODUCTION

In gasifiers, biomass is moving from zone to zone. Each zone is maintained at a constant temperature. At this temperature physical and chemical properties are changing. Drying, devolatilization and gasification occur simultaneously depending upon the surface temperature.

When the biomass is moving from one zone to another zone it experiences non isothermal heating temperature. Depending upon the non isothermal temperature the change of zone will take place. Total weight loss on heating alone can be used to follow the progress of reaction. The material, experimental set up and procedure for determining the total weight loss at a given interval of time are explained in this chapter.
8.2 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.

8.3 EXPERIMENTAL SET-UP

A muffle furnace (160 × 150 × 300 mm) has been used in this study. A temperature controller was used to maintain the temperature at any desired level. Samples of coir pith pellets of similar in size have been placed on separate steel cups. Air entry into the furnace will not be allowed. Each pellet was weighed accurately.

8.4 EXPERIMENTAL PROCEDURE

The muffle furnace was switched ON. Once the desired isothermal heating temperature of 200°C was reached and was maintained steadily, the 16 numbers of steel cups with the sample were inserted and the stopwatch was ON. At a regular interval of every 5 minutes, the marked sample was taken out, cooled in a desicator and then was weighed. The experiment was repeated 3 times and the average weight was taken for further calculations. This procedure was repeated for other isothermal heating temperatures of 250, 300, 350, 400, 450 and 500°C.

8.5 EXPERIMENTAL RESULTS

Tables A4.1 to A4.7 give the experimental data collected for various conditions. Figure 8.1 represents the weight fraction yet to be converted at various times, for all isothermal-heating temperatures.
It can be observed from the above data that complete ash was resulted at 500°C. The remaining weight 10% is the ash content of the sample. It proves that auto gasification of coir pith pellet is feasible. In all other temperatures around 86% to 72% weight loss has occurred.

Figure 8.1  Weight Fraction yet to be Converted at Different Isothermal Heating Temperature

The above curves were divided into three zones according to its different slopes between the time intervals. The first zone is in the time interval of 0 to 10 minutes, second zone is from 10 to 55 minutes and third zone is from 55 to 80 minutes. Figures 8.2 to 8.4 represents the zone I, II and III respectively.
Figure 8.2 Zone-I for Different Isothermal Heating Temperature

Figure 8.3 Zone-II for Different Isothermal Heating Temperature
8.6 ANALYSIS OF DATA

Data on weight fraction yet to be converted at every 5 minutes have been interpolated for every minute for all heating temperatures. Average temperature $\overline{T}$ has been determined using the procedure outlined in Chapter 7 (Section 7.5) for various operating conditions.

The rate of degradation (-rd) has been calculated by taking difference between subsequent weights and the average weights are obtained by averaging subsequent weights.

\[ -r_d = \frac{(w_{t-1} - w_t)}{\Delta t} \quad (8.1) \]

\[ w_{AV} = \frac{(w_{t-1} + w_t)}{2} \quad (8.2) \]
Using Equations (8.1) and (8.2) the rate of degradation (-rd) and average weight \((W_{Av})\) were calculated for every minute. The first order rate constant, \((k)\) was determined using equation given below:

\[
k = (- \text{rd}) / w_{Av}
\]  

(8.3)

Tables A4.8 to A4.28 give the thermal diffusivity \((\alpha)\), average temperature \((\overline{T})\) rate of degradation \((-\text{rd})\) and rate constant \((k)\) for the different zones and different isothermal heating temperatures respectively.

**8.7 EFFECT OF TEMPERATURE ON RATE CONSTANT**

The effect of average temperature \((\overline{T})\) on rate constant \((k)\) was obtained for all isothermal heating temperature \((Ts)\) ranging from 200°C to 500°C. Figures 8.5 to 8.7 depict these results for different zones. Rate constant \((k)\) and \(Ts\) and are related by fitting the data for different zones as follows:

For zone-I

\[
k = (7 \times 10^{-6}) \overline{T} + b_1
\]  

(8.4)

\[
b_1 = (1 \times 10^{-5}) \ Ts - 0.0033
\]  

(8.5)

For zone-II

\[
k = a_1 \overline{T} + b_2
\]  

(8.6)

\[
a_1 = (-0.0136 \ Ts + 9.0357) \times 10^{-5}
\]  

(8.7)

\[
b_2 = 1 \times 10^{-5} \ Ts + 0.01
\]  

(8.8)

For zone-III

\[
k = 2.67 \times 10^{-13} e^{26.219(\overline{T}/Ts)}
\]  

(8.9)

Zone –I is heat transfer controlled, therefore it does not depend on kinetics. In zone –II, the pyrolysis rate depends upon sample mass. Zone – III depends also on gases concentration; therefore it is not a first reaction.
Figure 8.5  Effect of Average Temperature on Rate Constant for Zone-I

Figure 8.6 Effect of Average Temperature on Rate Constant for Zone-II
Figure 8.7  Effect of (Average Temperature / Isothermal Temperature) on Rate Constant for Zone-III

8.8 EVALUATION OF MODELS

Equations (7.6), (7.5), (7.4), (8.4) to (8.9) were verified by calculating weight fraction yet to be converted (w) and by comparing with experimental weight fraction yet to be converted (w) for various isothermal heating temperatures of 200, 250, 300, 350, 400, 450 and 500°C.

The following calculation procedure was adopted:

1. Thermal diffusivity (α) was calculated using Equations (7.8), (7.7) and (7.6) for every minute.

2. For any assumed isothermal heating temperature (Ts), average temperatures (T̄) for every minute was determined using Equations (7.5) and (7.4).
3. The first order rate constant, \( k \) can be determined for isothermal heating temperature \( (T_s) \) and average temperatures \( (\bar{T}) \) at every minute using Equations (8.4) to (8.9) for different zones.

4. Weight fraction yet to be converted \( (w) \) can be calculated for every minute using

\[
w_t = w_{(t-1)} \{ (1-k/2) / (1+k/2) \}
\]  

(8.10)

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

5. The calculated and experimental weight fractions yet to be converted \( (w) \) were compared.

Tables A4.8 to A4.28 also give these values along with percentage error. Figures 8.8 to 8.10 compare the calculated and experimental weight fractions for various operating conditions satisfactorily with an error of \( \pm 1\% \) for zone-I, \( \pm 3\% \) for zone-II and zone-III.

![Figure 8.8 Comparison of Experimental and Calculated Weight Fraction yet to be Converted for Zone-I](image)

Figure 8.8  Comparison of Experimental and Calculated Weight Fraction yet to be Converted for Zone-I
Figure 8.9  Comparison of Experimental and Calculated Weight Fraction yet to be Converted for Zone-II

Figure 8.10  Comparison of Experimental and Calculated Weight Fraction yet to be Converted for Zone-III
8.9 CONCLUSION

Using the method proposed to determine thermal diffusivity at any time for any given surface isothermal temperature the average temperature within the coir pith pellet can be predicted. The rate constant can be determined at the average temperature. The weight fraction of pellet yet to be converted can be calculated. The proposed method is found to explain the experimental data satisfactorily.