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ESTIMATION OF KINETIC PARAMETERS OF NEWSPAPER WASTE WITH THE HELP OF BATCH TYPE PYROLYSER

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Abstract

To convert waste into fuel is a really challenging task because it is heterogeneous mixture of cellulosic and polymers. Waste-to-energy is possible either by thermal conversion or by bio degradation process and out of which thermal degradation occurs at a faster rate. To design such a reactor so that decomposition of waste composition occurs at a faster rate and efficiently the knowledge of kinetics is necessary. In general terms, kinetics is nothing but the measurement of rate of reaction. In the case of MSW, it is the measurement of decomposition of MSW with respect to both time and temperature. Based on this information, kinetic parameters such as activation energy (E) and pre exponent frequency factor (log A) can be calculated. This further enables one to predict how fast MSW component get consumed and release energy at different heating rates. The determination of weight loss with respect to temperature for different simulated constituents of MSW (cellulosic) at a fixed heating rate of 10 ˚ C/min in nitrogen environment using Batch Type Pyrolyser (BTP) is the first step in the kinetic study of MSW

***Keywords**:* activation energy (E), pre exponent frequency factor (log A), Batch Type Pyrolyser (BTP), Municipal Solid Waste (MSW), Thermogravimetric Analysis (TGA).

1. Introduction

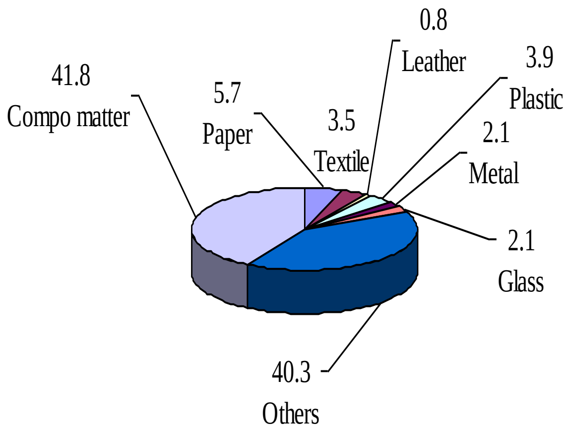
India is second largest country in the world from population, generating Municipal Solid Waste (MSW) around 42 million MT annually, Sunil Kumar, et al [1]; but to recover the energy from MSW efficiently and in eco-friendly manner is difficult task. A proper thermal treatment system not only resolves the disposal problems, but also recovers energy from these wastes.

To achieve this task it is necessary to design excellent quality thermal equipments (reactors); and to design such efficient thermal equipments like Incinerator, Pyrolyser and Gasifier the reliable data on hydrodynamic, heat transfer, and kinetics aspects are required to develop the reactors on a fundamental basis.

The kinetics is nothing but the measurement of rate of reaction; while in case of MSW it is decomposition rate of MSW with respect to both time and temperature and on the basis of which the kinetics parameters like activation energy (E) and pre frequency exponent factor (A) can be calculated. These then predicts how fast MSW composition or component get consumed and release the energy for different heating rates. The determination of kinetics constants is possible by analytical approach called Thermogravimetric Analysis (TGA). In case of TGA kinetic constants of material can be obtained considering the weight loss with respect to time and temperature for different heating rates and kinetics constants can be obtained by either using Arrhenius equation or other suitable numerical methods

2. Composition and Characteristics of Municipal Solid Waste

In this 'composition' refers to the limited list of components or constituents, such as paper, glass, metal, plastic and garbage, into which an aggregate of municipal waste may conveniently be separated.
'Characteristics' on the other hand, refers to those physical and chemical properties, which are relevant to the storage, collection, treatment and disposal of waste such as density, moisture content, calorific value and chemical composition.



Average Values of Composition of MSW in India, Kurian Joseph, [2]

The variations in composition and characteristics of wastes in different parts of the country underscores the profound influences of national income, socio-economic conditions, social developments and cultural practices, and thereby focuses attention on the importance of obtaining the data locally.

3. Materials and methods

3.1 REACTION KINETICS

The combustion kinetics concerned with the speed or velocity of a reaction in combustion processes. It is defined as the study of the elementary chemical reactions and their rates taking place in combustion it is called Combustion reaction kinetics.
The aim of combustion kinetics is to determine (a) The rate at which the molecules interact under certain condition (b) Description of speed as a function of the concentration of the reactants (c) The manner in which molecules interact or would react, when the conditions change (d) The factors which control the reaction rate (e) Mechanism through which reactant molecules transformed into products.

The rate of reaction is defined as "the rate of formation of one or more of its products or as the rate of consumption of one or more of its reactants." The rate of reaction is measured in terms of either the rate in decrease in the concentration of reactant(s) or the rate of increase in the concentration of product(s).

Arrhenius put forth a simple theory that accounts for this fact and gives a temperature dependency of k. Arrhenius stated that only molecules that possess energy greater than a certain amount E will react. Arrhenius' postulate may be written as

$$RR = \mathrm{A}\exp(-{}^{E}\!/_{RT})$$

A is kinetic pre-exponential factor and exp (-E/RT) is the Boltzmann factor. The state of the reacting species at this activated energy can be thought of as some intermediate complex that leads to the products. Generally, the more exothermic a reaction is the smaller the activation energy.

Thus the important conclusion is that the specific reaction rate constant k is dependent on temperature alone and is independent of concentration. Actually, when complex molecules are reacting, not every collision has the proper steric orientation for the specific reaction to take place.

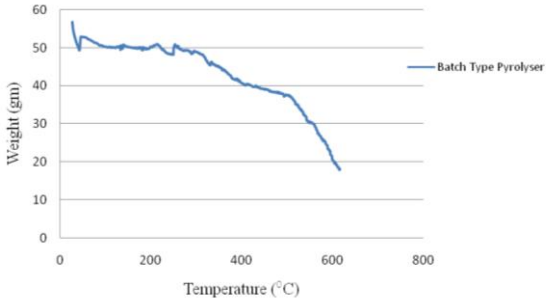
A is kinetic pre-exponential factor. An increase in k with T and permits convenient straight line correlations of data on in k versus (1/T) plots. The slope of lines on these plots of lines on these is equal to (-E/R) and thus the activation energy may be determined readily.

4. Results and discussion

The results obtained through Batch Type Pyrolyser in nitrogen atmosphere with heating rate of 10^0 C/min. The material have been used is news paper.

Fig shows the decomposition of newspaper waste with respect to temperature.

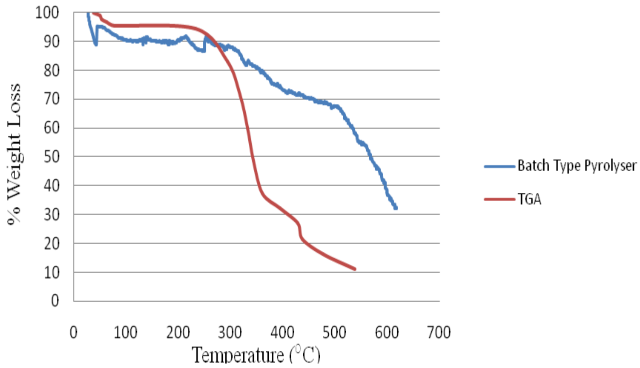
It is seen that the decomposition of newspaper waste takes place in three stages: 1.Hemicellulose 2.Cellulose 3.Lignin and printing ink in case of BTP. The some deviation seen in the decomposition curve due to gases evolved through the crucible.



Weight Loss w.r.t.Temperature for Newspaper Waste

The first stage decomposition ends at 13.84% weight loss and corresponding temperature is 267.1 ^{0}C. The second and third stage decomposition terminates after 32.7% and 65.41 % and corresponding temperatures are 498.3^{0}C and 611.6 ^{0}C respectively.

Fig shows comparison of decomposition in case of TGA and BTP in nitrogen atmosphere and at 10 ^{0}C/min heating rates.



Comparative Decomposition Analysis of TGA and Batch Type Pyrolyser for Newspaper Waste

The decomposition behavior is same in both TGA and BTP but trend are not overlapping due to heat and mass transfer resistance theory according to which in case of BTP as mass of sample in grams and so when heat get penetrated from one layer to the next due to conduction resistance and due to gases evolved resist the heat penetration and so the decomposition occurs in case of BTP at higher temperature than TGA as shown in Table.

Decomposition Stage Corresponding to Temperature for News Paper Waste

COMPONENT	STAGE	TGA		BTP	
		%wt	T(^{0}C)	%wt	T(^{0}C)

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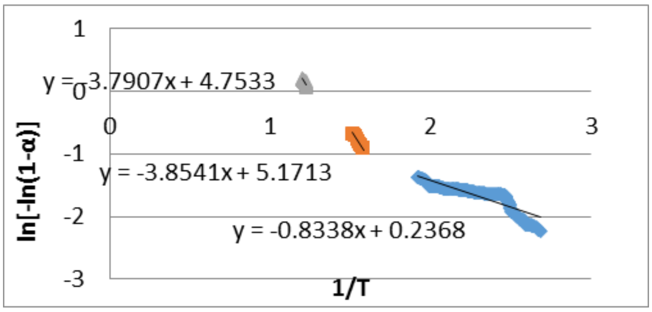
NEWS PAPER	**1**	82.96	294	86.16	267.1
	2	28.86	428.2	67.3	498.3
	3	11.18	538.3	34.59	611.6

The kinetics constants have been obtained as per method described and Table 5.2 shows that in second and third stages where decomposition occurs at the faster rate the value of activation energy is high while in first stage where with decomposition the moisture which was trapped in the composition also released due to which the activation energy value is low. At the same time due to rise in the temperature the value of logA increases due to enchantment in molecular collision.

Kinetic Constant for News Paper Waste

STAGE	Activation Energy (E) kJ/kmol	Pre Exponent Frequency Factor (log A)
1	15.95	0.24
2	73.79	5.17
3	72.57	4.75

Fig. shows the plot of ln [-ln (1-α)] Vs 1/T for newspaper waste. The plot is divided into three parts: hemi cellulosic, cellulosic and lignin.



4.1 Calculation for Activation energy (E):

Activation energy (E) = Slope *Gas Constant*2.303
In case of hemi cellulosic decomposition i.e. first stage slope = 0.833 (neglecting sign)
Gas Constant =8.314 kJ/kmol-K
E= 0.833*8.314*2.303= 15.95 kJ/kmol
Intercept on Y-axis = Pre-exponent Frequency Factor (logA) = 0.24

5. Conclusion

1. The kinetic study for different component of MSW shows their decomposition rate with the help of TG-DTG analytical approach

2. The kinetic parameters not only influence by heating rates but the atmosphere in which process takes place.
3. The kinetic parameters get affected by the mixture of MSW components compared to that of individual components.
4. Apart from heating rate there are other parameters such as depth of fixed bed and flow of nitrogen play a vital role in kinetic parameters.

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