Numerical Analysis of Waste Newspaper as Biomass for Extraction of Hydrogen

Saravana Sathiya Prabhahar.R[1], Pandiya Rajan.V[2], Nagaraj. P[3]
[1, 2, 3] *Department of Mechanical Engineering, Mepco Schlenk Engineering College (Autonomous), Sivakasi, India.*

Abstract: Biomass is considered to be one of the most promising renewable energy sources in the future. Due to stringent policy on emission reduction, biomass has become a centre of attention worldwide as a source of green energy. Biomass is biological material derived from living or recently lived organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally applied to both animal and vegetable derived material. There are basic categories of material virgin wood, energy crops, agricultural residues, food waste. Biomass gasification means combustion of biomass resulting in production of combustible gases consisting of carbon monoxide, hydrogen and trace of methane. This mixture is called producer gas. Many researchers investigated the yield of hydrogen by gasification using different biomass sources like rice husk, saw dust etc. In this research an effort is made to use the locally available waste (Waste Newspaper) as a biomass source to investigate the yield of hydrogen by gasification and also to identify the influence of different process parameters on hydrogen yield. In this present work the investigation of biomass calorific value, thermogravimetric analysis, proximate analysis and numerical analysis in CFX® were done.

Keywords— *Pyrolysis, Waste Newspaper, Thermogravimetric analysis, CFX®, Alternative fue..*

I. INTRODUCTION

Paper, which is one of the largest constituent of Municipal solid waste, has become a severe problem for disposal in developed and developing countries due to the shrinking landfill capacity. It is very important and challenging task in managing the solid waste. Newspaper, which is a cellulosic feed stock, is emerging as an attractive option for the production of bio-gas because of lower feedstock costs, higher potential for fossil fuel displacement and also there will be reduction in greenhouse gas emission as compared to production of hydrogen gas. Cellulosic resources are in general very widespread and plenty available. As they are not consumed by humans, their cost is relatively low. Some examples are – paper, cardboard, wood, fibrous plant material etc. Cellulosic materials are comprised of lignin, hemicellulose and cellulose and are thus called lingo-cellulosic feed stocks. The main objective of the current project is to minimize the newspaper load on municipal solid waste by efficiently utilizing the waste newspaper in the production of bio-gas Wu [1] studied kinetics and pyrolysis of mixture of four types of papers (uncoated and coated printing paper, newsprint and tissue paper) for heating rates 1, 2, 5 K/min and results indicated that decomposition occurred in two stages. Wu [2] studied pyrolysis of newspaper with TGA system at a constant heating rate of 5 K min−1 in nitrogen environment and analysed pyrolysis products. The residues were analysed using GC and an elemental analyzer. Bhuiyan[4] reported TGA studies for newspaper with heating rates 5, 10, 20 K/min for kinetic study and also carried out pyrolysis of newspaper waste. In present work, the thermogravimetric analysis of the newspaper waste at heating rate of 20ºC/min in the nitrogen atmosphere has been studied and the kinetic parameter (activation energy) is determined by using thermogravimetric curves. Singh RK [5] studied Activation energy from Pyrolysis of paper cup waste using thermogravimetric analysis. Singh RK [5] studied the paper cup waste at heating rate of 25° C/min, 30°C/min in the air and 30°C/min in the N_2 atmosphere and the kinetic parameter(activation energy) determined by using thermogravimetric curves.

II. MATERIALS AND METHODS

A. Raw Material

The waste newspaper used in the experiment was collected from the nearby areas. The paper were cut into small square shaped pieces (about 1 cm side), before use, so as to minimize voids inside the reactor as well as to fill maximum amount of material into the reactor.

B. Characterization of Raw Material

The newspaper waste was analyzed in order to observe the change in the properties of the solid material as a result of pyrolysis.

- *Proximate Analysis:* It provides information on moisture content, ash content, volatile matter content and fixed carbon content of the material.

- *Calorific Value:* Calorific value of a material is the amount of heat liberated when 0.5g of that material is burnt. It was determined for newspaper waste using a digital bomb calorimeter.

- *Thermo-Gravimetric Analysis:* Pyrolysis is heating of a substance in absence of medium at a particular temperature. Therefore, the temperature for effective pyrolysis of the newspaper waste has to be determined. For this purpose, thermo-gravimetric analysis (TGA) of the sample material was done using a DTG60 instrument. In nitrogen medium, around 5mg of sample was taken and heated up to a final temperature of 600°C and a residence time of 15 minute at 600°C was allowed. TGA was performed in nitrogen atmospheres at the heating rates of 20°C/min in nitrogen medium. Thermo-gravimetric weight loss curve was plotted against temperature. It provides a range of temperature in which maximum thermal degradation of newspaper waste takes place.

C. *Numerical Method and Boundary Conditions*

The whole laboratory scaled gasifier geometry domain is discretized into number of small cells and solved numerically using Upwind Difference Scheme. The fuel composition of waste newspaper is listed in table 2. The geometry for numerical simulation of the laboratory scaled gasifier is symmetrical about the longitudinal axis, so the 10˚ 'V' cut of longitudinal section and height of 416.67 mm (from bed to outlet) taken from scaled size of 1027 mm height and 133 mm of fluid path diameter having gasifier Fig 1 shows the model used in Ansys CFX® analysis. The biomasses are assumed to flow from the top of the gasifier and the fuel gas also come out from the top of the gasifier. The feed air inlet is in the bottom. The operating conditions of gasifier [3] is that the flow rate of biomasses was 0.23 kg/s. The velocity of feed gas was 0.27 m/s and the temperature 800˚C.

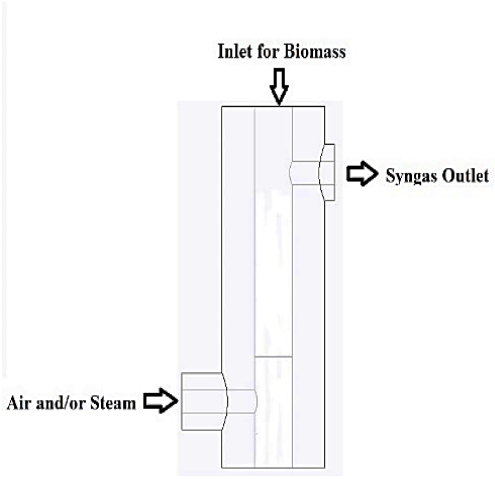

Fig.1 Scaled Model of Updraft Gasifier

III. Results and Discussion

A. *TGA and GCV Analysis of the Waste news paper Sample*

Thermogravimetric analysis (TGA) is a thermal analysis technique that measures the weight change of a material as a function of temperature and time, in a controlled environment. This can be very useful to investigate the thermal stability of a material, or to investigate its behavior in different atmospheres (e.g. inert or oxidizing). TGA was applied to study the thermal stability/degradation of waste newspaper in various ranges of temperature. From the TGA curve shown in Fig 2, the waste newspaper degradation started before 100°C and completed at 532°C for a heating rate of 20°C /min. The degradation temperature at which a weight loss of 50% (T_{50}) takes place was about 350°C for waste newspaper.

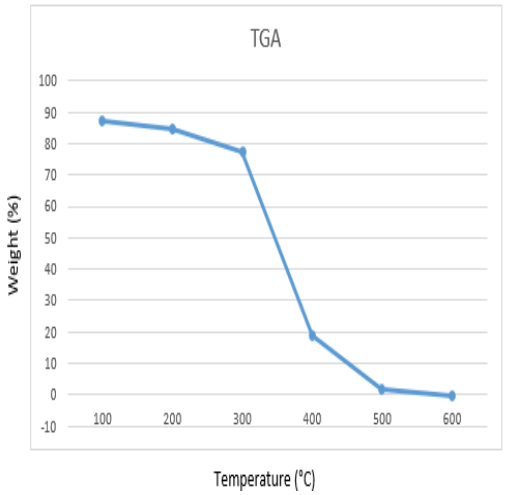

Figure 2. TGA Curve of Waste Newspaper

B. *FTIR of Waste Newspaper Samples*

Fourier Transform Infrared spectroscopy (FTIR) is an important analysis technique that detects various characteristic functional groups present in ash. Upon interaction of infrared light with oil, chemical bonds can absorb infrared radiation in specific wavelength ranges regardless of the structure of the rest of the molecules. Fig 3 shows the FTIR spectra of waste newspaper ash. The different assignments of the FTIR spectra of waste newspaper ash are summarized in Table I, which shows the presence of mostly arene and benzene.

TABLE I. FTIR ASSIGNMENTS OF WASTE NEWSPAPER ASH OBTAINED AT 450°C

Wave number(cm^{-1})	*Nature of functional group*
680	Arene and benzene
769	Arene and benzene
868	Arene and benzene
1011	Arene and benzene (bending in ring plane)
1412	Arene and benzene (stretch)

The wave numbers in Fig 3, obtained frome FTIR test shows that the arene&benezene combination always present in our sample whose bondings are stretched and bending in ring plane.

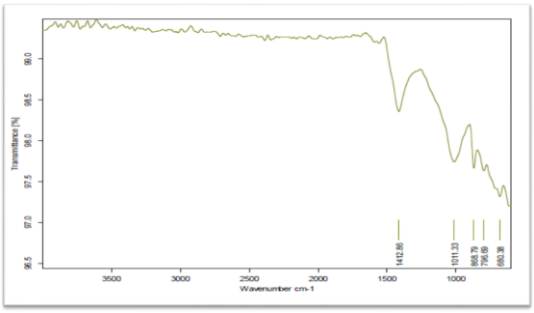

Figure 3. FTIR Spectra of Newspaper waste ash

C. Characterization of waste newspaper

Proximate analysis is the quickest and simplest way of investigating the fuel quality of solid materials. The proximate analysis of newspaper waste is shown in table II. Negligible moisture content of newspaper indicates negligible effect on the conversion efficiency and the heating value of the cellulosic biomass. Low ash content also indicates less impact on the heating value of newspaper. Volatile matter is very high whereas the remaining of fixed carbon owes to its cellulosic nature. These properties make Newspaper an efficient raw material for good quality fuel.

TABLE II. Characterization of Newspaper Waste

Proximate Analysis	***(wt%)***
Moisture Content	5.9
Volatile Matter	81.2
Ash Content	11.5
Fixed Carbon	1.4
GCV (kcal/kg)	3580.41

D. Simulation in ansys CFX®

The Ansys CFX® analysis was validated with literature [8]. The validation details are given below in Fig.4.

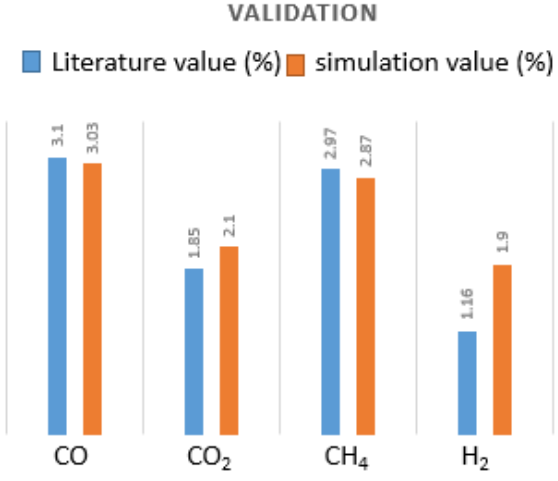

Figure 4. Validation of Ansys CFX® analysis

Waste newspaper was tested by Thermogravimetric analysis at 532˚C to complete burning happened. This temperature was given as input value in CFX® simulation. Analysis are shown in fig.5 to fig.8 that shows the mass fractions of CH_4, H_2, CO_2, and CO.

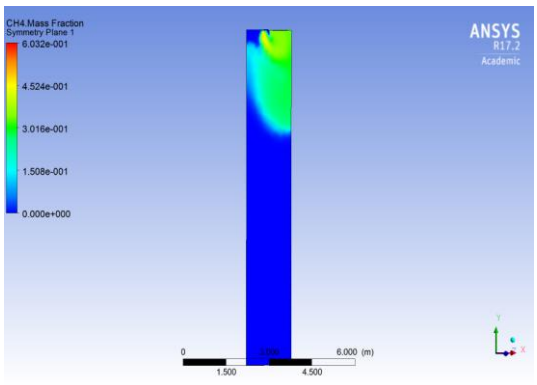

Fig 5: Mass Fraction of CH_4

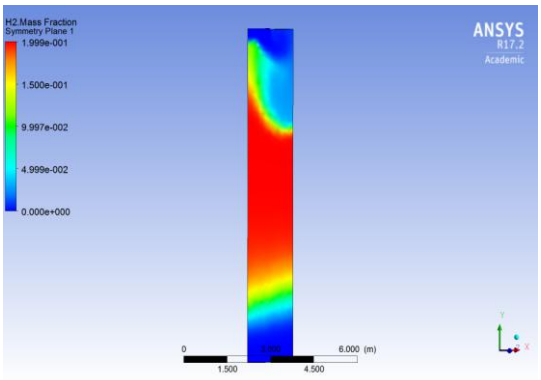

Fig 6: Mass Fraction of H_2

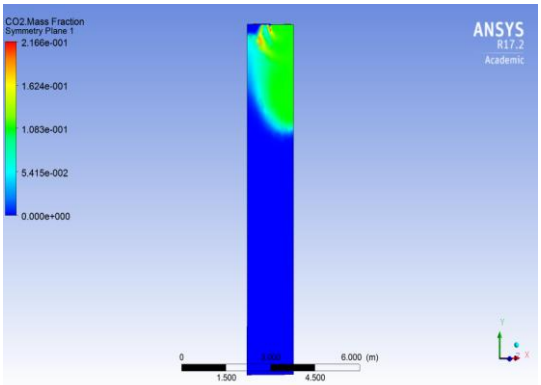

Fig 7: Mass Fraction of CO_2

In the mass fraction profiles the reactions takes place in the certain height because of the flow of primary air feed from bottom. In CH_4, CO_2 and CO mass fraction models the biomass is come from top and react at mid of the reactor and go to the outlet. The

CH_4, CO_2 and CO concentrations are decreases at exit because of continuous burning that increases the flue gases. In H_2 profile fig. 5 hydrogen concentration is more at the boundary of reaction starting place and decreases suddenly because of the water gas shift reaction takes place.

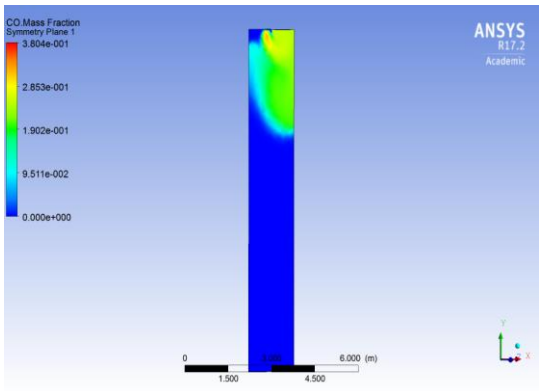

Fig 8: Mass Fraction of CO

IV. CONCLUSION

From the TGA curve, the paper waste degradation started at before 100°C and was completed at 532°C for a heating rate of 293 K/min in nitrogen atmosphere. The degradation temperature at which weight loss of 50% takes place was about 350°C for paper waste. The temperature range for paper waste was 300°C to 600°C, and maximum weight loss occurred at temperature of 532^{o}C. The FTIR study helps to interpret chemical bonding properties and the thermal behavior of the given type of cellulosic feedstock. The calorific Value of used material (Newspaper) was obtained as 3580.41kcal/kg. The existence of CO, CH_4 and H_2 were found in this sample (newspaper waste) 3.03%, 2.87% and 1.9% respectively. This indicates that the newspaper waste could be used as a fuel in variety of applications. The proximate analysis for moisture content, Volatile content, Ash content and fixed carbon are calculated.

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