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Research Article

Comparative Study of Temperature Effect on Gasification of Solid Wastes in a Fixed Bed

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Abstract

The temperature effect on the gasification technology of municipal solid waste has been investigated using a pilot scale fluidized bed gasifier by comparing the potentials of various waste types for production of syngas. This study investigates the production of synthesis gas from municipal solid wastes (agriculture waste, household waste, orange fruit waste and egg cover), by combustion in fluidized bed gasifier. As feedstock preparation plays a vital in the increase of performance of gasification, steps of feedstock preparation (sorting, shredding and dying) are enlightened in detailed. The composition of syngas produced at different stages of the experiment is presented. The purpose of this research was to estimate and compare the potentials of gasification process of municipal solid waste. Fluidized bed gasifier uses a relatively small amount of oxygen or water vapor to regenerate the organic compound into a combustible gas. This study found that higher amount(about 57%) of combustible gases (H_2 and CH_4) and lesser amount (about 42%) of CO_2were obtained from household waste, both agriculture waste and egg cover waste contain 51 % combustible gases (H_2 and CH_4) and 49% of CO and CO_2 respectively. While Fruits waste contains 54% combustible gases (H_2 and CH_4) and 44% of both CO and CO_2. Silica sand and municipal wastes are used as bed material in fluidized bed gasifies.

Keywords: Fluidized Bed; Syngas; Temperature; Gasification; Solid Waste

Introduction

As years go way, the demand of energy increases, and becomes clearer the need to search for new sources, renewable and non-polluting. That is the reason why in these last years the development and research on renewable sources of energy is coming more and more significant. Management and treatment of urban and industrial solid waste (garbage, recyclable materials, organic waste and hard waste) can mitigate adverse impacts on environment and human health, and also can support economic development and quality of life [1]. Municipal solid wastes (MSW), associated with nonindustrial human activity, are continually generated in large amounts around the world, creating problems with their disposal. Hence, enforces to think for sustainable waste disposal. Some thermo-chemical waste treatment methods (i.e. waste-to-energy conversion pathways such as, Pyrolysis, Gasification and Incineration) can transfer solid waste into energy, while gasification technology provides an efficient and environmental friendly solution to produce energy in the form of syngas [2]. Also here, gasification is the technique, which provides better solution to a problem than incineration technology [3].

Today, the world requirement for renewable energy sources is the key factor in the consideration of the fluidized bed gasification system. During gasification, the chemical energy inside municipal solid waste produces synthesis gas, and volume of solid waste can be quick decrease. Municipal waste is no more viewed as worthless garbage; the solid waste is rather perceived as an economic resource in the present time. Associated waste management system attempted a flexibility of waste analysis option base on different waste fraction like plastics, glass, and organic waste. The gasification process or approach could be analyzed by the environmental and social point of view.

In recent time, a number of Alternative Waste Technologies (AWTs) have been developed for solid waste treatment. AWTs show processes that generally, redirect waste away from landfill, pick up more resources from the waste stream and reduce the effect on the environment [4]. Following a detailed investigation and using multi-criteria analysis (MCA), it has been established that Gasification is a suitable technology for Australia among a number of available AWTs (Anaerobic Digestion, Pyrolysis, Incineration and Gasification) [2].

Gasification process converts biomass or solid waste by the addition of heat in an oxygen-starved environment. Recently, Kwon and Castaldi [5] investigated the enhanced gasification of Municipal Solid Waste (MSW) using carbon dioxide (CO_2) as the gasification medium to achieve environmentally caring and energy efficient ways for the disposal of MSW. They discovered that, there are two main steps of thermal decomposition of MSW: firstly thermal degradation step occurs at temperature between 2800C and 3500C and consists of the decomposition of the biomass component into light C1–3-hydrocarbons. The second thermal degradation step occurs between 3800C and 4500C and is mainly attributed to polymer components, such as plastics and rubber, in MSW. Belgiorno et al. [6] investigated the state of gasification technology, energy recovery systems, pre-treatments and prospect of syngas use with particular attention to the different process cycles and environmental impacts of solid wastes gasification. They identified gasification process offers energy

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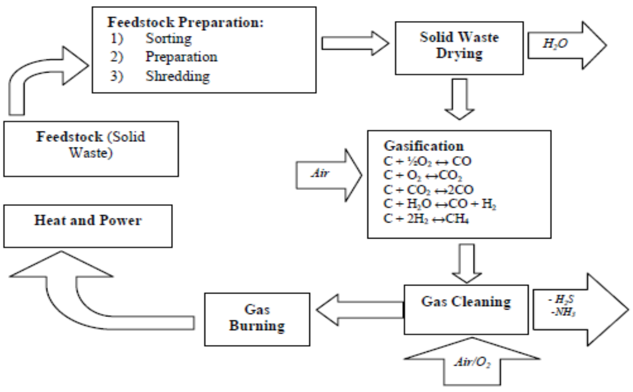

Figure 1: Schematic diagram of solid waste gasification process.

recovery and reduce the emission of potential pollutants. Gasification with pure oxygen results in a higher quality mixture of carbon monoxide and hydrogen and virtually no nitrogen. Gasification with steam is more commonly called 'reforming' and results in a hydrogen and carbon dioxide rich 'synthetic' gas (syn-gas). The gas has a calorific value of 4-10 MJ/Nm^3 and can be used to generate electricity [7]. Typically, the exothermic reaction between carbon and oxygen provides the heat energy required to drive the pyrolysis and char gasification reactions [8]. There are six basic reactions (1 - 6), that must be considered during the process. All of these reactions are reversible and their rates depend on the temperature, pressure and concentration of oxygen in the reactor [9]. A schematic diagram of the whole process is shown in Figures 1.

$$
\begin{array}{ll}
C + O_2 \rightarrow CO_2 & -393\ kj/mol\ (exothermic) \\
C + H_2O \rightarrow CO + H_2 & +131\ kj/mol\ (endothermic) \\
C + CO_2 \rightarrow 2CO & +172\ kj/mol\ (endothermic) \\
C + 2H_2 \rightarrow CH_4 & -74\ kj/mol\ (exothermic) \\
CO + H_2O \rightarrow CO_2 + H_2 & -41\ kj/mol\ (exothermic) \\
CO + 3H_2 \rightarrow CH_4 + H_2O & -205\ kj/mol\ (exothermic)
\end{array}
$$

Many researches on waste gasification have been reported in the literature. Liu et al. [10] compared various technologies of MSW disposal and found that thermal technologies have the most potential. Xiao et al. [11-13] investigated the gasification characteristics of components in MSW and concluded that organic components could be gasified efficiently between temperature range of 500–7000C. The gasification characteristics of MSW were studied at 500–7500C when equivalence ratio (ER) was 0.2–0.5 using a fluidized-bed gasifier. They found that when temperature was between 550–7000C and ER was 0.2–0.4, low heat value of syn-gas reaches up to 4000–12000 kJ/Nm^3. The purpose of this paper is to demonstrate a pilot scale gasification plant's experimental investigation and the effect of temperature on the quantity of syngas produced from different solid wastes. Partial fluidization was considered in this study in order to achieve faster drying and reaction rates. Composition of syngas at different stages of the experiment is presented.

Materials and Methods

Materials

In this study, a pilot-scale fluidized bed gasification process plant

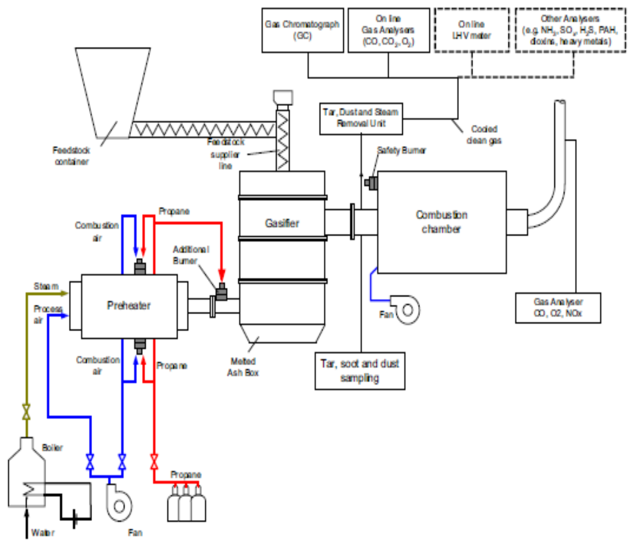

Figure 2: Schematic Diagram of the Experimental Setup of Solid Waste Gasification Process.

was used for syngas production from municipal solid waste. Generally, gasification process involves preparation of feedstock materials and plant set-up. Feed stocks (Food waste, yard waste wood, textiles, paper, etc.) are collected from the City of Yenagoa, Bayelsa State. Collected wastes are prepared and sorted. The gasification set-up comprises four modules: a waste pre-processing unit, the gasification/oxidation chambers, the energy recovery section and finally the flue gas cleaning module. In the pre-processing module the waste is sorted, grinded, shredded, stored and dried with the determination of obtaining a gasification-friendly feed material. The layout of the Gasification plant is shown in Figure 2. The main components of the plant are: waste receivable area, zerma shredder, screw feeder, reactor, hopper, scrubber, catalytic converter, combustion chamber, elemental analyzer, and gas chromatograph – mass spectrometer (GC-MS).

Method of experimental setup

To increase gasification performance, prepared feedstock was dried to reduce moisture. In the gasifier, the solid waste is continuously fed at a slow rate while steam and air is bed at the bottom. The solid waste undergoes devolatilization at the top of the gasifier. The char drops down slowly through the reactor. For the reason that the char in the bed are moving gradually. Gasification process reaction takes place in the vessel in the presence of air producing raw syngas. Syngas cleaning is done to remove the pollution from produced raw syngas. The gasifying vessel is 12 inches in diameter, and 8 feet long cylindrical stainless steel tube. The vessel could be operated at temperature as high as 1000 ^{0}C. Figure 2 shows the experimental set-up of the gasification. Silica sand is used as the bed material.

At the start of each experiment, 2.5kg of the bed material are fed to the fluidized bed reactor using the screw feeder; the bed was then fired using Liquefied Petroleum Gas (LPG) as a fuel at flow rate of 10-12 lh^{-1}. After the fluidized bed temperature increased to a desired level, the flow of the liquefied petroleum gas into the gasifier was stopped and the solid wastes were fed to the reactor by help of the attach feeder

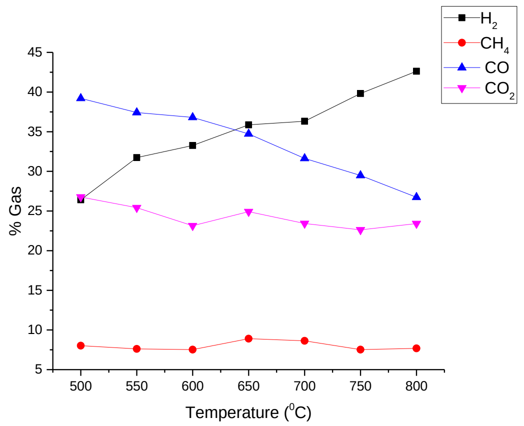

Figure 3: Temperature *vs* Product Gas Composition (vol.%).

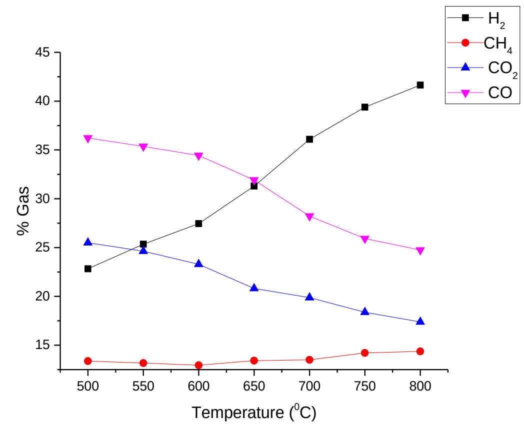

Figure 4: Temperature *vs* Product Gas Composition (vol.%).

Table 1: Operating parameters studied and their range.

S/N	Operating Parameter	Range
1	Temperature	500 – 800 °C
2	Bed material	3 - 4 kg
3	Feed rate	10-15 kg/hr
4	Equivalence ratio	0.3

and the gasification start. Table 1 shows the operating parameters of the gasifier.The filter was connected to outlet gas in which the solid particles are incarcerated by water and remaining particles captured by a filter of pore range 0.01-0.04 micron. Earlier than going to an analyzer the moisture present in the gas were removed by passing it throughout silica gel transferable infrared coal gas analyzer was used to measure the concentration of hydrogen, carbon monoxide, methane and carbon dioxide in the outlet gas.

Results

A. Effect of varying temperature on product gas composition at biomass agriculture waste

Agriculture waste by product gas composition (vol.%) at different temperatures effects on the composition of syn-gas is shown below (Figure 3).

B. Effect of varying temperature on product gas composition at household waste

Household waste by product gas composition (vol.%) at different temperatures effects on the composition of syn-gas is shown below (Figure 4).

C. Effect of varying temperature on product gas composition at fruit waste (orange)

Fruit waste by product gas composition (vol.%) at different temperatures effects on the composition of syn-gas is shown below (Figure 5).

D. Effect of varying temperature on product gas composition at egg cover waste

Egg covers waste by product gas composition (vol.%) at different temperatures effects on the composition of syn-gas is shown below (Figure 6).

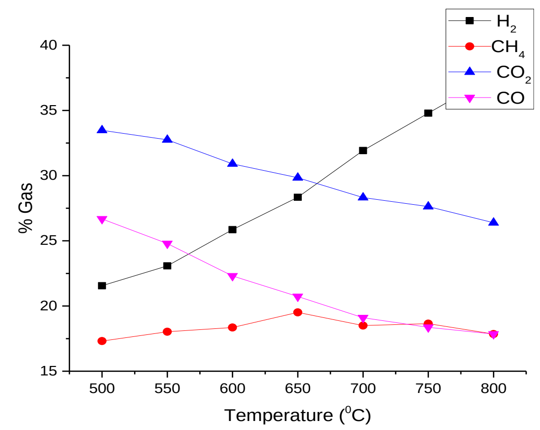

Figure 5: Temperature *vs* Product Gas Composition (vol.%).

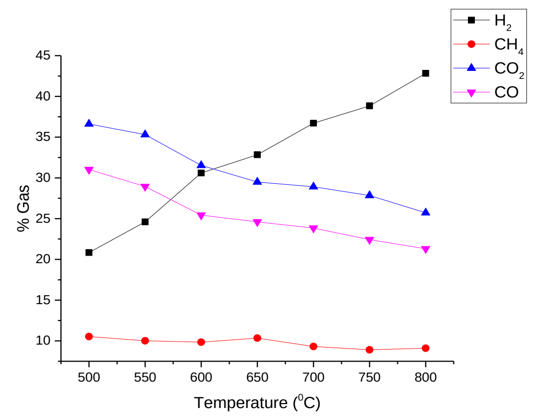

Figure 6: Temperature *vs* Product Gas Composition (vol.%).

Discussion

The gasification experiment has been carried out for syngas composition, such as, H_2, CO, CO_2 and CH_4 under equivalent condition concerning feed loading and fluidization settings. The temperatures in the gasification zone, which characterize the operating point at was between 500 - 800 °C in all experiments. The

Table 2: Experimental Analysis of Gases Produced from the feed stocks at maximum gasification temperature, 800^{0}C.

Waste Type	H_2 %	CH_4	CO %	CO_2 %
Agricultural waste	43	8	26	23
Household waste	43	14	25	17
Fruit waste	37	17	17	27
Egg cover waste	43	8	23	27

experimental results for optimal temperature, 800^{0}C are shown in Table 2. The report shows that fluidization behaviors of agricultural waste, household waste, egg cover and fruit waste (orange) are summarized in four experimental data. The air flow rate has been converted to corresponding equivalence ratio, which is defined the ratio of actual to stoichiometric mass of air supply per kg of fuel. In the deficiency of stoichiometric air or elemental composition in the reports. Therefore, a value of 10kg/hr of dry household waste, egg cover, rice husk and orange waste taken.

According to gasifier chemistry and the Boudouard reaction, with increasing operating temperature C is converted to CO. CH_4 is converted into H_2 by the reverse of the methanation reaction. Since, gasification process is an endothermic reaction; the product gas composition is responsive towards temperature change. As it can be from Figures 3 - 6, it was observed that the concentration of hydrogen (H_2) increased with increased temperature, and the concentration of methane (CH_4) decreases over the range of temperature. As a result with increase in temperature, the concentration of carbon monoxide increases in the product gas (higher temperature favors endothermic formation) and this approach leads to increased concentration of hydrogen. The water gas reaction implies that a high temperature increases the production of both CO and H_2. The CO_2 concentration decreased as the temperature increased. This is because endothermic reaction was more dominant, placing the reaction toward the right, and resulting in the increase of CO and decrease of CO_2 as the temperature increased. Similar trend has been observed in literature [14-17]. The comparison of fruit waste was more suitable than others. And higher energy source fruit waste. This leads to better yield of hydrogen but much higher steam flow rates will have a contrasting effect on gasification rate because it reduces the reactor temperature. The lower gasification temperature leads to higher char yield, and subsequently results in higher combustor temperature, hotter bed material, and higher gasification temperature, so that less char will be produced.

Conclusion

The experimental analysis of four different solid wastes namely, agriculture waste, household waste, orange fruit waste and egg cover waste gasification has been conducted using fluidized bed gasifier. The gasification process offers extensive energy recovery and reduces the emission of potential pollutants. It is consider an integrating and alternative to the conventional technology for the thermal treatment of solid waste. In any case, gasification is particularly suitable for homogenous agricultural, industrial waste household waste and fruits waste. The effects of feed flow and gasifier temperature on gasification performance is analyzed, discussed and compared to identify the most suitable operating conditions with agriculture waste, household waste, orange fruit waste and egg cover waste. The following results were identified: (1) gasifier temperature between 500 - 800 °C and air-fuel ratio of 0.3 is a good combination of operating conditions for all four feed stocks; (2) concentration of CO ranges 17%– 38% can be achieved at gasifier temperatures of 500°C to 800°C; (3) an air-fuel ratio of more than 0.3 provides decreasing CO concentration for all the wastes; and (4) concentration of H_2increases with the increase in temperature. The results obtained explained that the hydrogen concentration increase with increases temperature (500 - 800 ^{0}C). To this end, it is therefore concluded that using agriculture waste, household waste, orange fruit waste and egg cover can produce synthesis gas.

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