GASIFICATION IN FLUIDIZED BED: EFFECT OF USING OF THE AIR/STREAM AS GASIFYING AGENT ON THE SYNGAS COMPOSITION

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Abstract

In this work has been discussed the impact of various parameters on product gas components (gas,tar, char) and especially gasification medium that is taken into account are(air, pure steam, and steam O_2 mixtures) . The biomass air gasification has been developed actively for industrial applications. but it produces a gas with a low heating value (4–6 MJ/ m^3) and an 8–14 vol.% H_2 content only .Biomass oxygen-rich air gasification produces medium heating value (MHV) gas, but it needs a large investment for oxygen production equipment and this disadvantage impedes its popularization. Steam gasification produces a higher energy content producer gas. Steam-gasification processes (with or without O_2 added) are also capable of producing a MHV (10–16 MJ/Nm^3) gas with a 30–60 vol.% H_2 content. However, this technology requires that the temperature of steam be over 700 °C, which demands additional cost for steam generator of good performance.Under this background, the technology of biomass air gasification with low temperature steam was put forward from the economic point of view. This study has been based on previous researches

Keywords: Gasification, Gasifying Agent , Air ,Steam

INTRODUCTION

Biomass energy is the oldest energy source used by humans. Biomass has evolved as one of the most promising sources of fuel for the future. This has spurred the growth of research and development efforts in both federal and private sectors.This impetus is motivated by several factors; dwindling fossil fuels and thus an increase need of energy security, environmental concerns and promotion of socioeconomic benefits to rural areas. Another important fact is somewhat uniformly distributed nature of biomass worldwide which means it is available locally and is helpful in reducing the dependence upon the fossil fuel [1].Biomass is potentially an attractive feedstock for producing transportation fuels as its use contributes little or no net carbon dioxide to the atmosphere. Renewable biomass resources include short-rotation woody crops, herbaceous biomass, and agricultural residues. Biomass is available for exploitation for conversion to the bio-fuels as well as for power generation applications. There are various conversion technologies that can convert biomass resources into power, heat, and fuels for potential use in UEMOA countries. In view of this a variety of processes exists for biomass conversions. The most used of these are thermal conversions, bio-chemical and chemical conversions and direct combustion. The thermal conversion processes consist of fast and slow pyrolysis and biomass gasification . Biomass gasification is considered one of the most promising routes for syngas or combined heat and power production because of the potential for higher efficiency cycles Gasification is a process for converting carbonaceous materials to a combustible or synthetic gas (H_2, CO, CO_2, CH_4). In general, gasification involves the reaction of carbon with air, oxygen, steam, carbon dioxide, or a mixture of these gases at 700 °C or higher to produce a gaseous product that can be used to provide electric power and heat or as a raw material for the synthesis of chemicals, liquid fuels, or other gaseous fuels such as hydrogen[1].

GASIFICATION PROCESSES

Gasification is made up from four discrete thermal processes. Drying, Pyrolysis, Combustion and Reduction figure(1) [2].

Drying

Drying is what removes the moisture in the biomass before it enters Pyrolysis. All the moisture needs to be (or will be) removed from the fuel before any above 100 °C [3].

Pyrolysis or Devolatilization

A series of complex physical and chemical processes occur without air/oxygen , which start slowly from about 150 °C, to 700 °C Pyrolysis generally produces the following three products [2]:

1. Light gases such as H_2, CO, CO_2,CH_4
2. Tar
3. 3. Char

Combustion

The oxidation or combustion of char is one of the most important chemical reactions (Exothermic reaction).taking place inside a gasifier, providing practically all the thermal energy needed for the endothermic reactions [2]

$$C + O_2 \rightarrow CO_2 + 393.77\, kJ/mol \quad carbon.............1$$

$$H_2 + \frac{1}{2}O_2 = H_2O + 742\, kJ/mol \quad H_2 ....2$$

Reduction

Reduction is the removal of oxygen from an HC by adding heat. Combustion and Reduction are equal and opposite reactions. Through this process, CO2 is reduced to CO. And H_2O is reduced to H2 and CO. Combustion products become fuel gasses again [2].

$$C + H_2O \rightarrow CO + H_2 - 131.38\, kJ/mol \quad carbon.............3$$

$$CO + H_2O \rightarrow H_2 + CO_2 + 41.58\, kJ/mol ....4$$

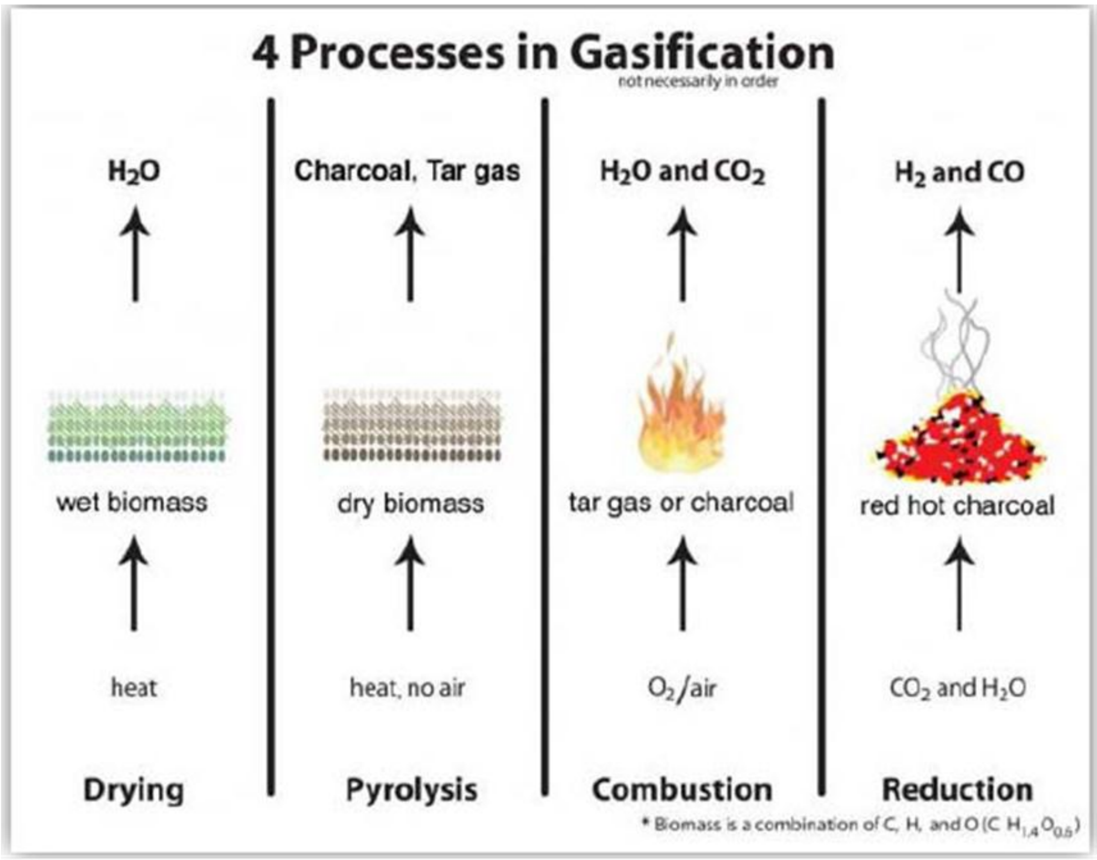

Figure (1) Processes of Gasification [3]

EFFECT OF VARIOUS PARAMETERS IN GASIFICATION PROCESS

Syngas composition varies widely, which is a mixture of carbon monoxide, methane, hydrogen, nitrogen, carbon dioxide, etc., depends upon the Various Parameters:

EQUIVALENCE RATIO

Equivalence ratio (ER), i.e. the ratio between the oxygen content in the oxidant supply and that required for complete stoichiometric combustion. Increase in ER increases the temperature inside the gasifier while ER decrease increases char formation inside the gasifier. Tar concentration decreases with increase in ER [4].

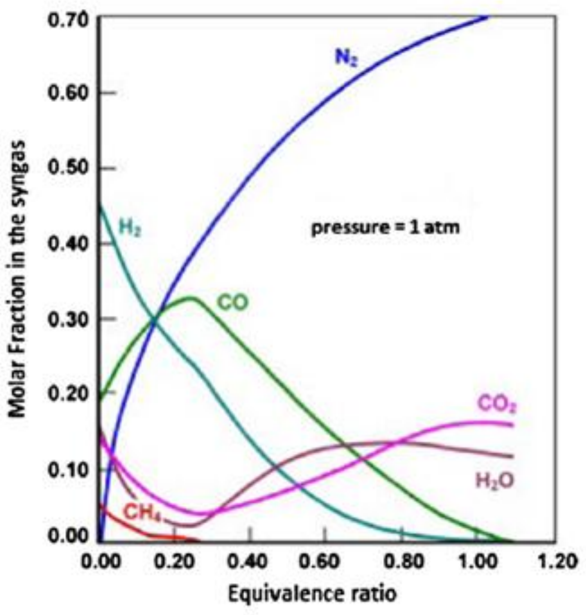

Fig. 2. Syngas composition at the chemical equilibrium as a function of equivalence ratio, for the gasification of wood at 1 atm (redrawn from Kaupp and Goss, 1981) [4].

Effects of Air-Biomass Ratio

When air-Biomass ratio is too little gasification temperature is too low to be beneficial to gasification reactions[6]. When air-Biomass ratio is too big excessive air makes combustible components combust again. thus it is bad to improve calorific value. In comparison, the less air-biomass ratio is the less calorific value. Improving air-biomass ratio effects on improves gasification temperature; gasification rate quickens and gas gross increases.

Temperature and Pressure

The temperature and the pressure of the gasifier have the greatest effect on the product composition. In CFB gasifier that the HHV of the produced gas increased by 10% for an increase in the temperature from 700 to 800 °C [5]. Increase in temperature reduces the tar content as well as decreases char inside the gasifier and tar cracking temperatures are often reported to be around 1000-1100 °C with some dependency on gasifier design CO_2 concentration increases with increasing pressures and decreases sharply with increasing temperatures[2].

- that the production of hydrogen and carbon monoxide increase with rising temperature and low pressure within the reactor. Maximum concentration of H_2 and CO can be obtained at atmospheric pressure and temperature range of 800 to 1000 °C [2].
- Concentration of methane in the product gas increases with low temperature and high pressure[2]

According to this results refer that to obtain high carbon monoxide content gas, the gasifier should be designed to work at a high temperature and low pressure

Carbon conversion efficiency η_c

Carbon conversion efficiency (η_c) that is defined as the ratio between the carbon flow rate converted to gaseous products and that fed to the reactor with the solid waste [7].

Carbon conversion efficiency, η_c (%) determined by [7]:

$$\eta_c = \frac{V_{gs}.1000\left[CH_4\% + CO\% + CO_2\% + 2\left(C_2H_4\% + C_2H_6\% + C_2H_2\%\right)\right].18/22.4.}{W\left(1 - X_{ash}\right).C\%} X100$$

where CH_4%, CO% (vol%), etc. are the gas concentrations and $V_g = Nm^3/h$ is the dry product gas flow rate, W is the dry biomass feeding rate (g/h), X_{ash} is the ash content in the feed, and C% is the carbon content in the ultimate analysis of biomass. It gives an indication of the amount of unconverted material that must be treated with other technique or sent to disposal, and then provides a measure of chemical efficiency of the process [7].

Gasification Medium

Thermochemical gasification of biomass is a well-known technology that can be classified depending on the gasifying agent: air, steam, steam–oxygen, air– steam, O_2-enriched air, etc.

Air gasification

The simplest gasification process uses air as a gasifying agent. Excess char formed by the pyrolysis process within the gasifier is burned with a limited supply of air (usually at an equivalence ratio of 0.25). The product is a low-energy gas containing primarily hydrogen and carbon monoxide diluted with the nitrogen from the air. The heating value of the produced gas is in the 3.5 - 7.8 MJ/Nm^3 range, which makes it suitable for boiler and engine applications but not for uses that require its transportation through pipelines. Air gasification is widely used compared to oxygen and steam due to its economical and operational advantages [5].

Cao et al. (2005) demonstrated a fluidized bed air gasification system using sawdust. They combined two individual regions of pyrolysis, gasification, and combustion of biomass in one reactor. The primary air stream and the biomass feedstock were introduced into the gasifier from the bottom and the top, respectively. Secondary air was injected into the upper region of the reactor to maintain elevated temperature. The study indicated that under optimum operating conditions, a fuel gas could be produced at a rate of about 3.0 Nm^3/kg biomass and heating value of about 5.0 MJ/Nm^3. The concentration of hydrogen, carbon monoxide and methane in the fuel gas produced were 9.27%, 9.25% and 4.21%, respectively [8].

Steam gasification

Steam gasification requires an external heat source if steam is used as a sole gasifying agent. Using a mixture of steam and air as a gasifying agent. Oxygen in the air will help to provide the required energy due to the exothermic nature of burning biomass. The elevated temperature will help in the devolatilization process of biomass to produce various gases. Steam will react with carbon monoxide to produce hydrogen and carbon dioxide[8]:

$$CO + H_2O \rightarrow CO_2 + H_2 \quad \text{...............11}$$

Compared to air gasification, steam gasification produces a higher energy content producer gas. Hoveland et al. (1982) studied corn grain-dust gasification in a 0.05 m I.D. fluidized bed gasifier using steam as a fluidizing agent and a mixture of sand and limestone as the bed material. The produced gas yield increased from 0.13 m^3/kg at 867 K to 0.73 m^3/kg at 1033K. The gas heating value increased from 9.4 to 11.5 MJ/m^3 at the same temperature range[8].

Corella et al. (1989) reported on steam gasification of four different crop residues (wood chips, thistle, saw-dust and straw) in a 0.15 m I.D. fluidized bed gasifier. They determined the gas, char, and tar yield at temperatures between 650-780 °C for each type of crop residue. Straw and sawdust exhibited higher gas and lower tar yields compared to wood chips and thistle[8].

Oxygen gasification

One effective way of producing medium heating value (MHV) gas (approximately 12-21 MJ/Nm^3),and product gas will not contain nitrogen and thus. Such a gas can be economically distributed in pipeline network systems and therefore, be conveniently used for process heat or possibly as synthesis gas to produce chemical and fuels. In this case, an oxygen plant or a nearby source of oxygen is required, which may elevate the capital cost necessary for the plant installation and this disadvantage impedes its popularization [2] .nd has, in fact, been studied by several researchers [8].

Tillman (1987) gasified municipal solid waste in an oxygen gasifier. The feedstock (shredded and magnetically sorted) was fed into the top of the gasifier and the oxygen was fed at the bottom. Pyrolytic char was combusted with the oxygen at the bottom of the gasifier providing enough thermal energy to produce temperatures in the range of 1593-1704°C and to produce a molten slag from all noncombustible materials. The maximum mole fraction of the produced gas for CO, H_2, CO_2 and CH_4 recorded were 44%, 31%, 13% and 4%, respectivelyThe maximum heating value was 10.6 MJ/Nm^3.[5]

Under the best and/or selected (indicated below) conditions (and without in-bed use of dolomite) the representative main results for the three gasifying agents are in Table1:[5] Biomass gasification can be done with any of the following medium[5]:

Table1: compare the representative main results for the three gasifying agents [8]

Gasifying agent			
Result/parameter	Air ER =0.3 , H/C =2.2	Steam-O_2 GR(Gasifying ratio [(H_2O+O_2)/Biomass, (kg/h)/(kgdaf/h)]=0.90 H_2O/O_2=3	Steam S/B=0.90)
H_2 (vol %, dry basis)	8-10	25-30	53 -54
CO (vol %, dry basis)	16-18	43-47	21-22
LHV (MJ/m^3_n, dry basis)	4.5-6.5	12.5-13.0	12.7-13.3
Y_{gas}(m^3_n, dry basis/kg daf)	1.7-2.0	1.0-1.1	1.3-1.4
Y_{tar} (g/kg daf)	6-30	8-40	70
Tar content (g/m^3_n)	2-20	4-30	30-80

Effect of Steam to Biomass Ratio (S/B)

The introduction of steam greatly improved gas yield, LHV and carbon conversion efficiency but increase in the S/B range from 1.35 to 4.04, gas yield, LHV and carbon conversion efficiency exhibited decreasing trends, which can be explained by that excessive quantity of low temperature steam lowered reaction temperature and then caused gas quality to degrade [7].

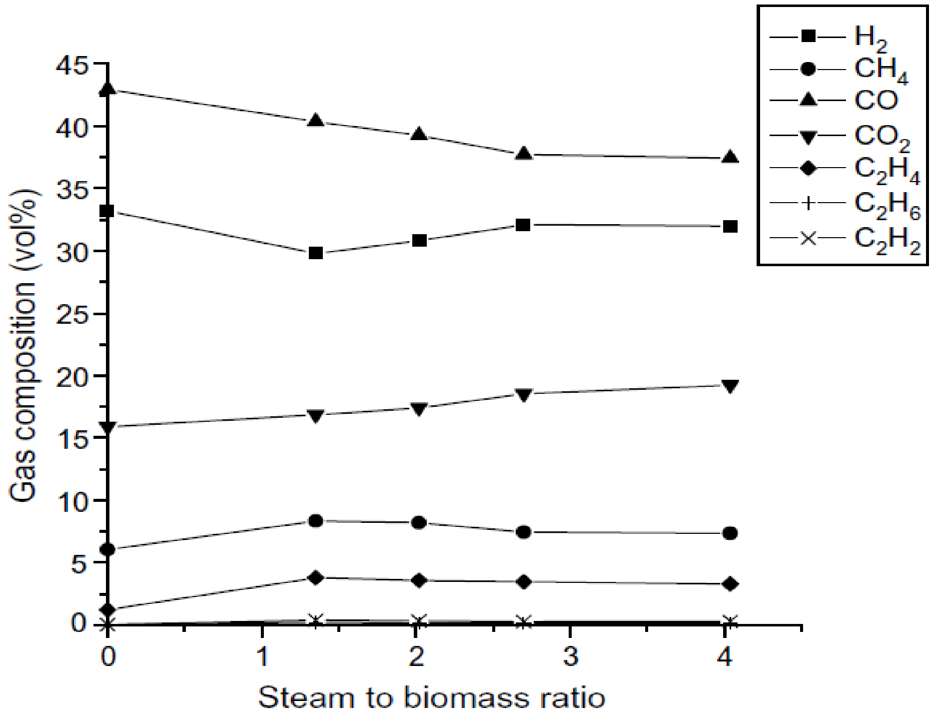

figure 2 Effect of S/B on gas composition biomass feed rate: 0.445 kg/h[] temperature: 800 C air: 0.5 Nm3/h.[7]

As shown in Fig. 2, in the S/B range from 0 to 1.35, CO concentration decreased and the content of CH_4, CO_2, and C_2H_4 increased because of steam introduction. Over the S/B range from 1.35 to 2.70, the content of CO, CH_4 and C_2H_4 decreased gradually, whereas CO_2 and H_2 concentration showed a moderate increasing trend.This can be explained by that there were more steam reforming reactions of CO, CH_4 and C_2H_4 taking place because of the increased steam quantity. When S/B was larger than 2.70, gas composition experienced little variation as shown in Fig. 2.

Air/steam ratio

Increasing the air to steam ratio increases the gas heating value until it peaks. when the steam-air ratio increased, the heating value increased, reaching its peak at 0.25 kg/kg[2].

CONCLUSION

- The technology of biomass air gasification seems to have a feasible application and has been developed actively for industrial applications. However this technology produces a gas with a low heating value (4–6 MJ/ m^3) and an 8–14 vol.% H_2 content only
- Biomass oxygen-rich air gasification isone effective way of producing medium heating value (MHV) gas, but it needs a large investment for oxygen production equipment and this disadvantage impedes its popularization.
- Steam gasification produces a higher energy content producer gas. Steam-gasification processes (with or without O_2 added) are also capable of producing a MHV (10–16 MJ/Nm^3) gas with a 30–60 vol.% H_2 content. However, this technology requires that the temperature of steam be over 700 °C, which demands additional cost for steam generator of good performance.

Under this background, the technology of biomass air gasification with low temperature steam was put forward from the economic point of view. Since the steam gasification reactions are endothermic as a whole, the process must be supplied with energy. This can be done by partial combustion of biomass within the gasifier using a hypostoichiometric amount of air.

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