Power generation via small scale biomass gasification process – A review

Jeet Prakash Sharma and Dr. Ravindra D. Jilte

Lovely Professional University, Punjab, India

Abstract

When it comes to substitute the power generation by fossil fuels, no other technology except biomass gasification prevails better. Even though the large scale biomass gasification (<2 MW) is obvious choice for the power generation due to high "efficiency to investment ratio". However, the small scale gasification process (> 200 kW) can be better choice in small region. This review paper is based on the small scale gasification technologies and their effects. This paper also includes the types of gasifier, biomass composition, particle size and gasifying agents.

1 Introduction

2 Gasification technologies

Gasification is one of the thermochemical processes which allow the conversion of carbon based materials into syngas (CO, H2, CO2, & CH4). The gasification takes place in the presence of oxygen or steam (gasifying agents) at the temperature of 700^0 C [1]. Gasification technology was used at the time of WW-II for the production of syngas with the combination of Fischer-Tropsch process. In the year 1973, there was huge oil crisis and due to that reason the America built the 12,000 large scale gasifiers (1 MW) [2]. The gasification process includes basically 4 steps known as, (i) Heating/ Drying, (ii) Decomposition, (iii) Oxidation, (iv) Reduction.

In heating/drying step, the moisture content (almost 30–60 %) gets vaporized and gets reduced to almost 15%. this step takes place at the temperature of 200 ^{0}C [3]. In the decomposition step, cellulose and hemicelluloses gets decomposed into volatile compounds and remains solid residue. This step takes place at the temperature of 220 ^{0}C [4]. In the oxidation step, the gasifying agent helps oxidizing the volatile compounds into , CO2, and H2O. This step takes place at the temperature of 700 ^{0}C. The next step is reduction step takes place at the temperature of 800 ^{0}C [5].

2.1 Biomass composition

Biomasses have different composition and changing composition can lead to change in efficiency [5]. Among all other properties, moisture content in biomass is very important because it provides the information about required energy in heating/drying step [6]. The volatile matter is mainly composed of gases and organic vapors which is result of decomposition step of gasification process. However, tar at high temperature converts into chunk of non-volatile residue. The carbon content is mainly the non-volatile compounds) [7]. The other constitutes of biomass are hemi-cellulose, cellulose & lignin. It has been seen that as the composition of lignin increases in biomass, the decomposition step becomes rather slower thus it require even higher temperature yet yield low syngas [8].

2.2 Gasifying agents

The gasifying agents are the crucial elements in the gasification process. The gasifying agents have different compositions and different reactivity. Mostly, oxygen (air), steam and CO_2 are used widely. However, air remains the most common gasifying agents because of its low cost and eases of availability. It has been seen that the high nitrogen content in air ultimately decreases the syngas heating value. The only drawback is that this will increase the operating cost of gasification process. The oxidation process mainly depends upon ER. In basic cases, the ER value is usually is lower than 1 to shun the full combustion. For the calculation of final heating value, ER is very important factor. Steam is used as gasifying agent when there is requirement of more hydrogen and less tar. However, this process is fairly more energy consuming because of its endothermic nature [9]. It is also seen that the air mixed with 40–70 mol% of steam obtained the optimum gas quality [10].

2.3 Biomass particle size

Another factor to influence the gasification process is known as the particle size of biomass. Basically, small particle size is responsible for yielding efficient heat transfer and faster reaction rate in gasification reactions [11]. Thus, the small particles in the gasification process yield high amount of syngas and low tar. However, the large biomass particle produces more char because of incomplete decomposition process [12]. Gasifiers are designed according to the biomass particle sizes.

2.4 Operating conditions

As the gasification temperature increases, CO and H2 yield also increases and tar content decreases and carbon conversion also go up with increasing temperature [13]. High lignin content in biomass requires high gasification temperature for maximum syngas yield and also larger particle size also require the high temperature [14]. Normal gasification temperature is around 700 ^{0}C but in case of steam gasification the temperature requirement goes up by 50 ^{0}C. Usually the gasification process takes place at constant pressure however pressurized gasification is very popular these days. Small-scale gasifier operates at atmospheric pressure to keep the cost low. However, it has been proven that the pressurized gasification process excel at efficiency and also result in low tar as compared to the conventional procedure but the cost is too high [6]. However form the chemical prospective it is better if the gasification process is performed at high temperature and low pressure for the sake of chemical equilibrium [12].

2.5 Gasifier types

Widely used gasifiers are given as follows:

1. fixed bed gasifier
2. fluidized bed gasifier
3. entrained flow gasifier

2.5.1 Fixed bed gasifier

The simplest kind of gasifier is known as the fixed bed or moving bed gasifier. There are two types of fixed bed gasifiers: (i) updraft and (ii) downdraft. In the updraft gasifier, the biomass is fed from the top and the gasifying agents are fed from the bottom in the reactor vessel. It also known as counter-current gasifier. This type of gasifier is capable of carrying out gasification process with high thermal efficiency. It can also deal with the high moisture content up to 60%. This gasifier can deal with the particle size in the range of 5–100 mm [15]. Since it generates more tar from the pyrolysis zone and lowers the temperature thus it is not much used [4]. In downdraft gasifier, the gasifying agent and biomass both are fed from the top. The tar production is low and whole region can reach to the high temperature and can convert all the tar [15]. But it can only deal with the low moisture content biomass such as 30%. Its carbon conversion efficiency is lower as compared to the updraft gasifier also it can only deal with the particle size in the range of 40 to 100 mm. tis is most suited gasifier for 10 kW-1 MW [16][17].

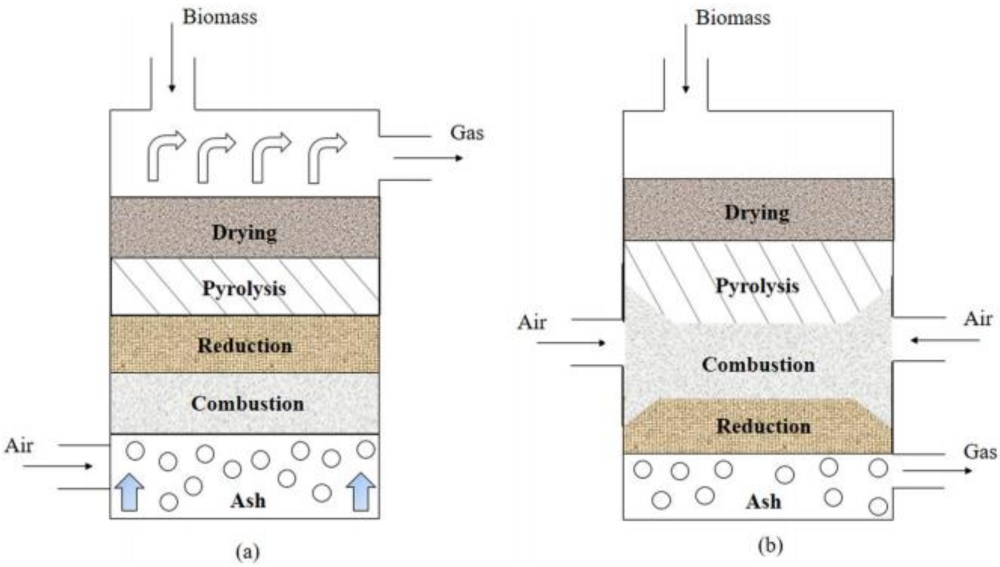

Figure 1: (a) updraft (b) downdraft gasifier designs [18]

2.5.2 Fluidized bed gasifier

This type of gasifier is better for efficient heat transfer and mixing of biomass and gasifying agents as compared to the fixed bed. It has homogenous distribution of temperature thus it allows the decomposition process to take place faster. The uniformity of temperature is attained by fluidized bed of biomass and the gasification takes places at almost isothermal conditions [19]. The bed materials the most crucial part in fluidized bed gasification. Usually, silica sand is the best choice due to it high heat capacity. At high temperature, the alkali compounds of biomass reacts with silica and form agglomeration. The conversion efficiency of fluidized bed gasifier is up to 95% [15]. Fluidized bed gasifier has two types named as BFBG and CFBG. In BFBG, the fluidization velocity remains below than 5 m/s to create bubbles. It provides the better flexibility for biomass treatment but it has very low efficiency [20]. In CFBG, the fluidization velocity is 3-5 times higher than BFBG.

2.5.3. Entrained flow gasifier

Entrained flow gasifier comes into picture when there is a need to handle the very fine biomass particles (75–100 μm). It was used for the gasification of coal at high temperatures (1400-1800 ^{0}C). It has a very short residence time (1-5 s). Since it deal with the fine particles thus the conversion is almost 100%. This type of gasifiers are mostly being used in the commercial coal processing.

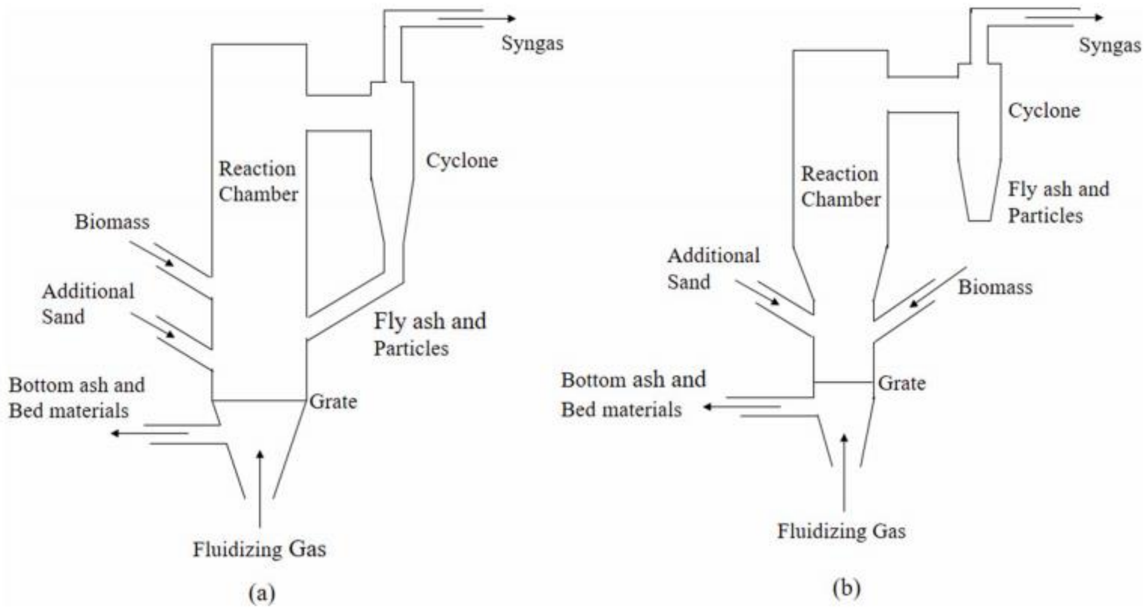

Figure 2: (a) bubbling (b) circulating fluidized bed gasifier [18]

Conclusion

Syngas production via gasification is futuristic alternative source of energy and also for the generation of electricity. Gasification has many advantages such as environmental and economic and compare to this fossil fuel application seem very steep. Small scale biomass gasification is best possible choice for electricity production in local areas. It keeps the cost low and supply is not too difficult. Many countries around the globe including India have vast potential market for the application of small scale gasification systems. Thus in all best scenarios, to conserve the environment and low cost energy production, biomass gasification emerges as best choice.

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