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Barriers of commercial power generation using biomass gasification gas: A review

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ABSTRACT

Gasification is one of the promising technologies to convert biomass to gaseous fuels for distributed power generation. However, the commercial exploitation of biomass energy suffers from a number of logistics and technological challenges. In this review, the barriers in each of the steps from the collection of biomass to electricity generation are highlighted. The effects of parameters in supply chain management, pretreatment and conversion of biomass to gas, and cleaning and utilization of gas for power generation are discussed. Based on the studies, until recently, the gasification of biomass and gas cleaning are the most challenging part. For electricity generation, either using engine or gas turbine requires a stringent specification of gas composition and tar concentration in the product gas. Different types of updraft and downdraft gasifiers have been developed for gasification and a number of physical and catalytic tar separation methods have been investigated. However, the most efficient and popular one is yet to be developed for commercial purpose. In fact, the efficient gasification and gas cleaning methods can produce highly burnable gas with less tar content, so as to reduce the total consumption of biomass for a desired quantity of electricity generation. According to the recent report, an advanced gasification method with efficient tar cleaning can significantly reduce the biomass consumption, and thus the logistics and biomass pretreatment problems can be ultimately reduced.

Contents

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1. Introduction

Gasification is one of the promising technologies to exploit energy from renewable biomass, which is derived from all living matters, and thus is located everywhere on the earth. Forest residues such as dead trees and wood chips, agricultural residues, municipal organic wastes, and animal wastes are common examples of biomass. The advantages of utilizing these biomasses for energy could be accounted for as it is carbon neutral and homogeneously distributed all over the world. Therefore, the utilization of biomass energy can provide dual benefits: it can reduce carbon dioxide (CO_2) emission as well as increase fuel security as it is produced locally. Despite the many advantages of biomass energy it is not being used in commercial scale because of many challenges associated with supply chain management and conversion technologies.

Although biomass is available locally all over the world it is widely distributed across regions. For example, forest residues are distributed throughout the forest and so are agricultural residues in the rural area. In addition, biomass is excessively moist at the source which makes it difficult to transport, irregular in size, and thus difficult to feed into the conversion unit. Therefore, development of a biomass based power generation facility needs several factors to be considered such as supply chain management [1–3], pretreatment of biomass [4–6], conversion of biomass to fuel gas [7–8], and, cleaning and utilization of fuel gas for power generation [9–12].

In the supply chain management, harvesting, collection, refining and transportation of biomass are key issues to be facilitated by the supply chain operation management. Since raw biomass, especially agricultural biomass, is excessively wet (> 50 wt%), it is not feasible to store it at the place of origin [13]. In other words, transportation of raw biomass is cost intensive [14]. Therefore, for sustainable supply of biomass to the biomass based power generation system needs optimum supply chain management, adopting available technologies. In addition, since the origin of biomass is often in the rural area, the entire supply chain system requires extensive involvement of the local community. Therefore, the success of biomass energy production also partly depends on the motivation and satisfaction of the grower who grows biomass at the root level [15].

Biomass conversion to fuel gas, which is termed as gasification, is the key technology for biomass based power generation. In order to produce optimum fuel gas composition for turbines or internal combustion engines, the optimization of multiple parameters including gasifier types (updraft, down draft), gasifying agent (air, steam), temperature, pressure and air-fuel ratio is essential [9]. The updraft gasifier can be further classified as fixed bed and fluidized bed. The fluidized bed gasifier is advantageous in terms of homogeneous heat distribution throughout the reactor and fast heat transfer rate to the particle, which facilitate the reaction rate. However, this process essentially requires tiny particles of biomass, the making of which is energy and cost intensive [16]. The fixed bed gasifier, which may be updraft or downdraft, is a simple construction and generally operates with high carbon conversion, long residence time, and low gas velocity. This method is suitable for small scale power generation. In addition, the selection of feedstock is equally important, because the composition of biomass significantly affects the product gas composition [17]. Moreover, some impurities such as tar, particulate matter, sulfur oxides, nitrogen oxides and ammonia always exist in the product gas. However, the internal combustion engine can only accept a very limited concentration of these contaminants [18]. It imposes the mandatory cleaning of the product gas by removing the contaminants to a certain minimum level. Among the contaminants, tar is the notorious one; it is a sticky material and deposits in the downstream equipment and blocks the narrow supply line [19].

Physical filtration of this sticky material creates two severe problems: (1) it blocks the pores of the filter and creates a pressure drop [19], and (2) tar consists of toxic chemicals (aromatic hydrocarbons), and thus handling and disposing of it is a health and environmental issue [20]. Catalytic hot gas cleaning is the most promising method, which provides multiple advantages such as (1) tar can be almost completely removed [21], (2) tar can be converted to product gas [22] and (3) other contaminants can also be trapped in the catalyst bed [22].

Table 1
Detail data related to collection, storage and delivery cost of biomass in different countries.

Biomass type	Origin of biomass, region/country	Physical nature of biomass	Mode of delivery	Costs related to collection, storage and delivery in US$ t^{-1}	Reference
Rice straw	China	Bulky	Satellite storage delivery	9.22	[27,34]
Mixed agricultural biomass	China	Bulky	Direct delivery	11.29	[35]
Switch grass	Great Plains, USA	Bulky	Direct delivery	75–83	[28]
Corn stover	Great Plains, USA	Bulky	Direct delivery	60–75	[28]
Agricultural/forest	Italy	Dense and high moisture	–	44/98	[29]
Agricultural/forest	Spain	Bulk/dense		30/66	[29]
Agricultural/forest	Portugal	Bulk/dense	–	28/36	[29]
Crops	India	Bulky	Multi-collection center	26-27	[30]
Wood	Japan	Dense	Supply region 9	166	[31]