



Tar reduction in biomass producer gas via mechanical, catalytic and thermal methods: A review

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ABSTRACT

Biomass gasification presents highly interesting possibilities for expanding the utilization of biomass as power generation using internal combustion engines or turbines. However, the need to reduce the tar in the producer gas is very important. The successful application of producer gas depends not only on the quantity of tar, but also on its properties and compositions, which is associated with the dew-point of tar components. Class 5, 4, and 2 tar become a major cause of condensation which can foul the engines and turbines. Hence, the selectivity of tar treatment method to remove or convert class 5, 4, and 2 tar is a challenge in producer gas utilization. This review was conducted to present the recent studies in tar treatment from biomass gasification. The new technologies with their strengths and the weaknesses in term of tar reduction are discussed.

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Contents

1. Introduction	2355
2. Tar definition, classification and treatment	2356
3. Mechanical/physical methods	2358
3.1. Dry gas cleaning	2358
3.2. Wet gas cleaning	2359
4. Catalytic cracking	2361
4.1. Nickel-based catalysts	2362
4.2. Non-nickel metal catalysts	2365
4.3. Alkali metal catalysts	2367
4.4. Basic catalysts	2368
4.5. Acid catalysts	2369
4.6. Activated carbon catalysts	2370
5. Thermal treatment	2371
5.1. Thermal cracking	2371
5.2. Plasma cracking	2373
6. Conclusions	2373
References	2374

1. Introduction

Global climate change due to CO₂ emissions is currently debated around the world. This issue has become a major concern and has encouraged the researchers to look for greener sources of energy as

alternatives to replace the fossil fuels. Therefore, research activities on renewable energy sources has become more and more important. One of the renewable energy sources is biomass.

Biomass can be converted into energy via thermo-chemical processes such as gasification, direct combustion, and pyrolysis. Among them, biomass gasification presents highly interesting possibilities for expanding the utilization of biomass. Biomass gasification is a thermal conversion process where solid fuel is converted into a combustible gas (producer gas) using gasifying agent

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Table 1
Composition of major gas products from biomass gasification [3].

Gasifying agent	Temperature range (°C)	Gas product (vol.%)						
		H ₂	CO	CO ₂	CH ₄	C ₂ s	N ₂	H ₂ O
Air	780–830	5–16	10–22	9–19	2–6	0–3	42–62	11–34
Steam	750–780	38–56	17–32	13–17	7–12	2	0	52–60
Steam + O ₂	785–830	14–32	43–52	14–36	6–8	3–4	0	38–61

such as air, steam, etc. It occurs in three stages and begins with drying where inherent moisture in the biomass is removed, then pyrolysis where volatile gases are released, and finally gasification where partial oxidation of residues and volatiles occur. Composition of producer gas from biomass gasification in an atmospheric bubbling fluidized bed gasifier as a function of gasifying agent is shown in Table 1.

Producer gas from biomass gasification can be utilized in internal combustion engines or turbines as power generation, especially in remote areas with no electricity supply. A successful demonstration of a high pressure, low heating value (LHV) gas, biomass integrated gasification and combined cycle (IGCC) was completed in 2000 in the city of Varnarmo, Sweden. This facility is fueled with about 18 MWth equivalent of wood residues and produces about 6 MW of electricity (4 MWe from the gas turbine and 2 MWe from the steam cycle) and 9 MW of heat. The producer gas has a low heating value of about 5–6 MJ/Nm³ [1]. Lim and Zainal [2] reported that bubbling fluidized bed gasifiers (BFBG) has potential for rural electrification projects especially in third world countries where biomass supplies are abundant from agricultural industries and where electricity supply from the grid is not available. For rural electrification projects, the bioenergy system is able to supply 100 kWe through a diesel generator, enough for electricity consumption of 50 households.

As the most promising biomass utilization method, gasification produces not only useful fuel gases, char and chemicals, but also some unwanted byproducts like fly ash, NO_x, SO₂ and tar. Generally, byproducts can cause erosion and corrosion on metals. Belgioirio et al. [4] reported the types of contaminants contained in the producer gas and the potential problems that can be generated as shown in Table 2.

Based on the above description, it is clear that the producer gas from biomass gasification, although providing benefits as an alternative fuel to replace fossil fuel but also has serious problems caused by the byproducts. Tar as one of the contaminants in the producer gas is the main concern of many researchers. Up to now, a great amount of work on tar removal or reduction have been reported. Definition and classification of tar are also reviewed to clearly highlight the condensation, composition, and quantity of tar and the downstream application to which the definition of tar is being applied.

Table 2
Contaminant presence in the gas and relative problems [4].

Contaminant	Presence	Problems
Particulates	Derive from ash, char, condensing compounds and bed material for the fluidized bed reactor	Cause erosion of metallic components and environmental pollution
Alkali metals	Alkali metals compounds, specially sodium and potassium, exist in vapour phase	Alkali metals cause high-temperature corrosion of metal, because of the stripping off of their protective oxide layer
Fuel-bound nitrogen	Cause potential emissions problems by forming NO _x during combustion	NO _x pollution
Sulfur and chlorine	Usually sulfur and chlorine contents of biomass and waste are not considered to be a problem	Could cause dangerous pollutants and acid corrosion of metals
Tar	It is bituminous oil constituted by a complex mixture of oxygenated hydrocarbons existing in vapour phase in the producer gas, it is difficult to remove by simple condensation	Clog filters and valves and produce metallic corrosion

2. Tar definition, classification and treatment

Until now, many definitions of tar have been reported. It is usually influenced by the gas quality specifications required for a particular end-use application and how the tar is collected and analysed. One of the definition of tar was reported by Milne et al. [5] as follows: The organics produced under thermal or partial-oxidation regimes (gasification) of any organic material are called “tar” and are generally assumed to be largely aromatic. However, newly contemplated applications of producer gas, such as fuel cells, may be affected by “non-condensables” such as ethylene, cyclopentadiene, and benzene. Other authors describe tar as a complex mixture of condensable hydrocarbons, which includes single to multiple ring aromatic compounds along with other oxygen containing hydrocarbons and complex polycyclic aromatic hydrocarbons [6]. While in the meeting of the IEA Bioenergy Gasification Task, the Directorate General for Energy of the European Commission (DG XVII) and US DoE has decided to define tar as hydrocarbons with molecular weight higher than benzene [7].

Different classifications for tar are found in several literatures [5,6,8]. Milne et al. [5] classified tar into four product classes: (1) primary products which are characterized by cellulose-derived, hemicellulose-derived and lignin-derived products; (2) secondary products which are characterized by phenolics and olefins; (3) alkyl tertiary products which are mainly methyl derivatives of aromatic compounds; and (4) condensed tertiary products which are PAH series without substituent. Primary products are destroyed before the tertiary products appear. Tertiary aromatics can be formed from cellulose and lignin, although higher molecular weight aromatics were formed faster from the lignin-derived products [5].

On the other hand, tar components can be classified into five classes based on their chemical, solubility and condensability of different tar compounds, rather than reactivity of the compounds, as given in Table 3 [6,8,9]. This classification system has been developed by Energy research Center of The Netherlands (ECN), Toegepast Natuurwetenschappelijk Onderzoek (TNO) and University of Twente (UT) in the framework of the project ‘Primary measures for the reduction of tar production in fluidized-bed gasifiers’, funded by the Dutch Agency for Research in Sustainable Energy (SDE) [9].

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