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Characterization of tar content in the syngas produced in a downdraft type fixed bed gasification system from dried sewage sludge

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ABSTRACT

Tar yields in the syngas produced in a pilot-scale downdraft type fixed bed gasification system from dried sewage sludge have been quantified and characterized to identify the effect of equivalence ratio (ER of 0.29–0.36). The increase of ER resulted in higher temperature of oxidation zone because air promoted the combustion reaction. High ER and high temperature also enhanced cracking and combustion of tar. Lower tar mass was observed while increasing ER. The change in tar composition with the change of ER was also observed by using the size exclusion chromatography (SEC). The SEC results showed that heavier molecular tar (in the molecular weight range of 300–500 u) formed whereas lighter molecular tar decreased under the higher ER conditions. Tar removal performances of the gas cleaning system (the venturi scrubbers and the sawdust adsorbers) were also investigated. The tar removal efficiency of the gas cleaning system depended on gasification conditions, tar components and the amount of tar. Tar content in the syngas was reduced to 26–53% and 14–36% (by weight) at the exit of the scrubbers and sawdust adsorbers, respectively. By the action of this gas cleaning system, about 44% of light aromatic hydrocarbon tar was removed while no light PAH tar was detected at the exit of the gas cleaning system.

1. Introduction

Sewage sludge is a residue by-product produced from waste water treatment plants. Sewage sludge contains 78–99% liquids by weight, depending on the waste water treatment methods, while the remaining part is solid such as metals, organic toxics, and pathogenic microorganism [1]. Alternative and sustainable sewage sludge disposal methods should be considered in regarding to the ecological and economical awareness. Thermal processes such as gasification are existing technologies to convert sewage sludge into combustible gas and leave heavy metals in the residual solid ash for final disposal. A downdraft type fixed bed gasification process is intended to manage sewage sludge since it produces combustible gas having less tar [2–4]. Due to relatively low tar content in the syngas produced in downdraft gasifiers, uncomplicated gas cleaning system can adequately produce clean syngas; as a result, only small space is required to install such system. Furthermore, the syngas can be used as a fuel for internal combustion engines.

In a downdraft gasifier, the volatile as well as tar will be released under high temperature in the pyrolysis zone and will be cracked and oxidized under favor of high temperature and oxygen in the oxidation zone. Most of researchers studied downdraft gasifiers reported only on tar mass production [5–8]. Little information on tar compositions produced in downdraft gasifiers is available especially for sewage sludge gasification. Adegoroye et al. reported on tar characterization for gasification of sewage sludge using the spouted bed reactor [9], but the nature of produced tar was actually different due to difference in the reactor used. Therefore, the produced tar should be quite different from the one observed in this study in both quality and quantity due to no cracking and oxidizing reactions in the spouted bed gasifier.

In this work, a pilot-scale downdraft type fixed bed gasifier with a gas cleaning system has been studied. This project is aiming at converting unwanted sewage sludge into a clean fuel gas for a dual-fuel diesel engine to generate electricity which should be supplied to the waste water treatment plant. The most important operating parameter affecting tar production is the amount of air supply. This effect is reported in view of the quality and quantity of tar. In addition, tar removal performance of the gas cleaning system is also reported in this paper.

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2. Material and methods

2.1. Pilot-scale gasification system

The pilot-scale downdraft type gasification system used in this study has been designed and developed by King Mongkut's University of Technology North Bangkok, Thailand as shown in Fig. 1(a). Six thermocouples were installed along the height of the gasifier in order to measure temperature inside the gasifier and classify the reaction zones. The dimension of the gasifier and positions of the thermocouples are presented in Fig. 1(b). The gas cleaning system consists of three main parts: (1) dust separators, (2) tar removers and (3) moisture captors. The recycled water supplied from the waste water treatment plant was used as scrubbing liquid which

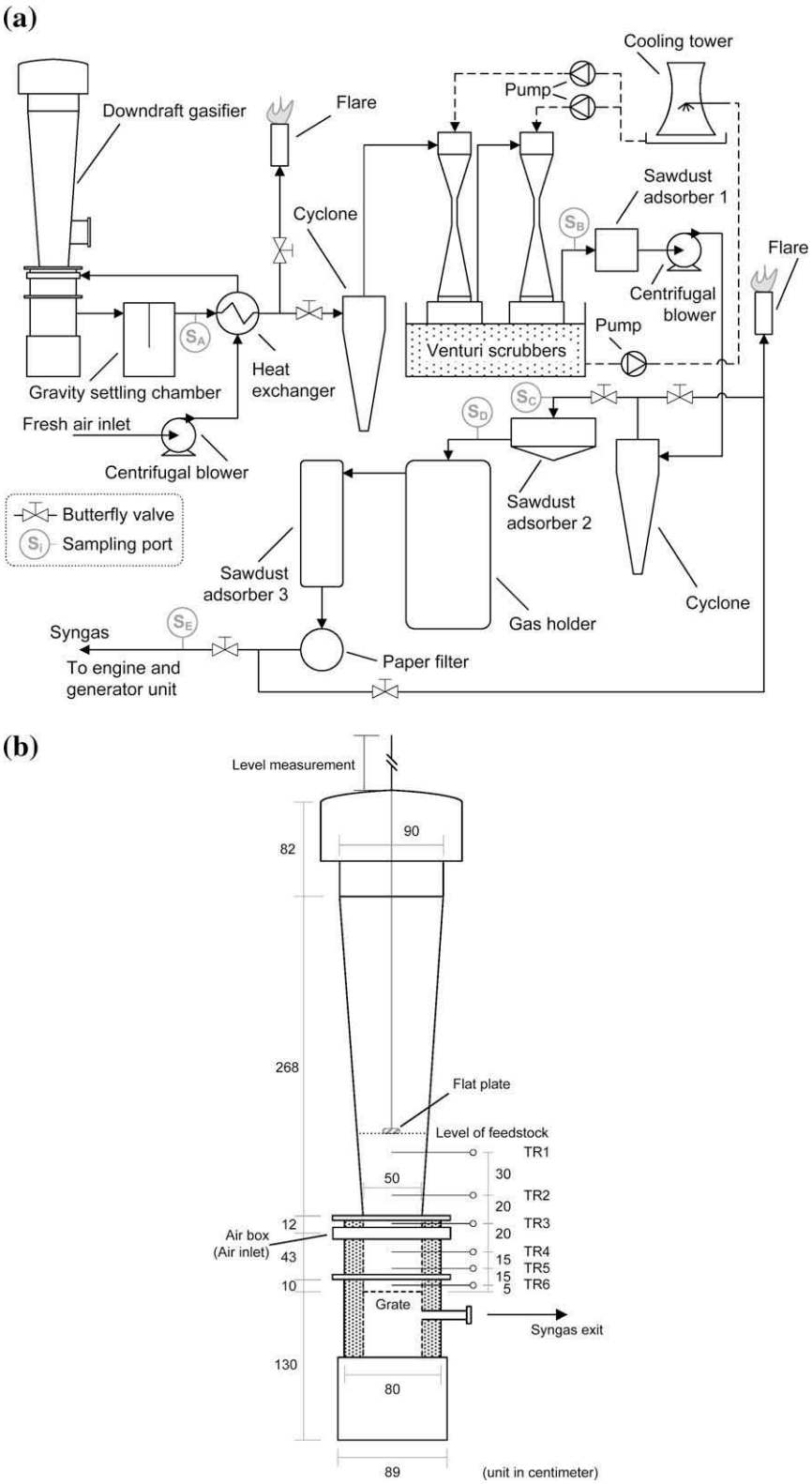

Fig. 1. (a) Schematic diagram of the gasification system and (b) dimension of the gasifier, positions of the thermocouples and measuring level of feedstock.