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EVALUATING THE APPLICATION OF BUBBLE WET SCRUBBER SYSTEMS FOR GAS CLEANING IN GASIFICATION

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Abstract: The removal of alkaline chemicals, particulates, and other impurities from syngas is a challenge in the biomass gasification process. Wet scrubbers are frequently used to clean the industrial exhaust gases before being released into the atmosphere. Cleaning fluid is sprayed or pumped through the apertures and comes in touch with the gas to be cleaned of most wet scrubbers. Therefore, this paper proposes a new technology that uses a bubble wet scrubber system to flow syngas at a constant height into a pool of cleaning water. The syngas will come into direct contact with the cleaning water to form bubbles containing gas and other impurities that are absorbed mostly by the cleaning water. The objective of this study is to develop a simple and cost-effective bubble system scrubber and investigate its impact on the scrubber's performance for tar removal from biomass gasification. The results show that 2.6 L of cleaning water can remove particles and tar from syngas with an 83.26% efficiency.

Keywords: Bubble, effectivities, syngas, wet scrubber, gas purification, particulate removal.

Introduction: The gasification system has been selected and designed to reduce impurities, but the gasification process still requires additional processing units to clean the syngas. These additional units include the cyclone separator and scrubber or filter, where each additional unit has the characteristics of removing one or several contaminants or impurities. The gasification system that generates syngas must include an additional unit capable of removing five major impurities, including particulate matter, alkali content, tar, nitrogen- containing components, and sulfur [1]. The fuel gas must also contain a minimal amount of light hydrocarbons, such as methane or ethane, even though these two hydrocarbons are actually useful as fuel gas because they can increase the syngas' heating value.

Gas cleaning is an essential component of any biomass gas installation in order to meet the end-user specifications for syngas. For example, for applications as fuel in internal combustion engines (ICE), which require tar compound and particulate concentration limits of around 100 mg/Nm^3 and 30 mg/Nm^3, respectively [2]. Conventionally, gas cleaning is performed using various systems, such as wet-dry and wet- cleaning. Most frequently, wet scrubbers are utilized in gasification processes for cleaning syngas, conditioning gas temperatures, and capturing smaller particles.

1. MATERIALS AND METHODS

Materials: The materials used to evaluate the performance of the cyclone separator were 20 kg of empty palm fruit bunches adjusted to the volume capacity of the gasification reactor chamber and 150 mL of an isopropanol solution with a concentration of 98% used as a tar and particle trap. Meanwhile, the equipment used included a downdraft fixed- bed type gasification reactor with a capacity of 200 kg (for wood chips) and 20 kg (for oil palm fruit bunches); a wet scrubber built according to Figure 1; a Konax-6501 anemometer to measure gas flow velocity.

Methods: The performance test of the water bubble column scrubber was conducted in conjunction with cyclones, blowers, and gasification reactors via 5-inch galvanized pipes and ¾-inch flexible pipes (Figure 2). The scrubber chamber is filled with cleaning water with a capacity of 2.6 L until it reaches a depth of 14 cm from the bottom. Temperature measuring devices, gas samples, and pressure gauges are installed in their respective designed positions.

2.2.2 Bubble circulation velocity: Bubbles will form in a liquid when a gas is introduced into it at a specific velocity. The liquid will circulate in the column if the gas is continuously flowing. The velocity value resulting from the circulation of this liquid can be determined using the following formula [7].

$$v_c = 1.36\left[gD\left(v_g - \varepsilon_g v_b\right)\right]^{\frac{1}{3}} \quad (1)$$

2.2.3 Gas bubble circulation time: Circulation time (t) is the ratio between the diameter of the bubble and its slip velocity. The bubble slip velocity is the bubbles' relative velocity to the circulating liquid. The velocity of liquid circulation and bubbles is calculated using Eq. (8).

$$t = \frac{d_b}{v_c - v_b} \quad (2)$$

2.2.4 Exit gas concentration The exit gas concentration is the ratio of the gas velocity and concentration entering the liquid to the total velocity of gas bubble production and gas velocity. The concentration of the exit gas can be determined using the following formula [10, 11]:

$$C_{\text{out}} = \frac{v_g}{\varepsilon_b v_b + v_g} C_{\text{in}} \quad (3)$$

3. RESULTS AND DISCUSSION.

In general, there are three methods for reducing tar compounds and impurity particles, i.e., impaction, absorption, and diffusion. The impaction method is very effective for particles larger than 0.1 m, whereas the diffusion and absorption methods are effective for particles smaller than 0.1 m [13]. The results of the cyclone analysis indicated that particles with a cut-size diameter between 0.828 m and 0.892 m at temperatures between 30℃ and 70℃ could be removed, allowing the syngas, which still contains smaller sized particles not captured by the cyclone, to enter the wet scrubber. The tar can be eliminated with considerably less effort by employing a bubble-flow type wet scrubber. Nonetheless, if the tar produced by the biomass gasification process is non-polar (classes 3 and 4), then water molecules cannot dissolve this type of tar [3].

3.1 Temperature distribution, gas and water physical properties.

The temperature distribution of gas and water in the wet scrubber equipment used for syngas cleaning can be seen in Figure 3. During the gasification time range of 50–100 minutes, the water temperature rises from 45–50℃ after the gas enters the scrubber. After 150 minutes, the temperature of water and gas tends to remain constant between 50 and 55℃. This condition indicates that heat has been transferred from syngas containing impurities and other compounds to water, which serves as a coolant and cleaning agent.

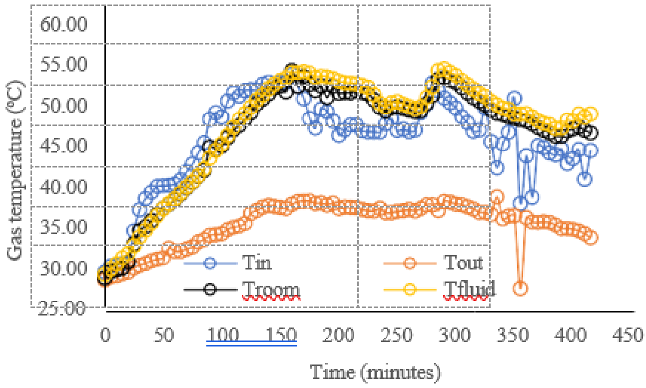

Figure 3. Temperature distribution on the wet scrubber equipment unit

As a result of accumulation, the water temperature will gradually rise. This also affects the temperature of the released gas, which increases to 35–45℃ or decreases by 10–15℃ on average when absorbed by water. Temperature variations have an effect on the cleaning water gas's physical properties, i.e., the density and surface tension. The density of gas and water is calculated using Eq. (2), where the density and surface tension values of water at temperatures of 30, 35, 40, 45, 50, 55 and 60oC obtained are 995.87, 992.66, 989.42, 986.14, 982.83, 979.48, and 976.09 kg/m3 , respectively; meanwhile the surface tension values of water are 0.071, 0.070, 0.069, 0.069, 0.068, 0.067, and 0.066 N/m, respectively. Temperature variations caused by the interaction of water and gas will have an effect on bubble characteristics, gas concentration, and pressure drop.

4. CONCLUSIONS

The wet scrubber device was developed by using water as a cleaning medium and cooling syngas from empty fruit bunch gasification with a gas flow pattern in contact with water to form syngas-filled bubbles. This study measures and analyzes pressure drop, which is an important parameter in determining the device's power requirements for flowing gas. The results of the experiment's analysis and measurements revealed a 1.60% difference in error between the measured and analytical pressure values of 109.67 and 107.82 mmH2O, respectively. The characteristics of the bubbles produced have a significant impact on the concentration of syngas that remains after leaving the scrubber device, and the concentration of syngas is 9.00% for CO and CO2, 24.00% for CH4, and 0.00% for H2 based on the findings of this study.

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