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Gasification of Lignite by Microwaved Steam

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ABSTRACT: Within the next 20 years, the production of oil and natural gas are expected to decrease and their cost is expected to increase continuously. Renewable energy sources will not be able to cover the total energy demand in the world; some countries will replace oil and natural gas with nuclear energy, while others with coal. Therefore, it is important to develop coal technologies, which are clean and efficient. Coal syngas has been widely used both in energy and chemical feedstock. Gasification process is a very slow reaction and needs high temperature, i.e. at least 1000°C minimum to have excellent gasification. Use of microwave energy in increasing gasification yields and reaction rates is of considerable interest since it will influence the reactivity of steam, and even supply endothermic heat of reaction from free radical energy. The effect of microwave discharge on coal gasification had been studied in order to reduce temperature of the operation and achieved high conversion of coal. There are some characteristics of microwave energy that will speed up free extreme reactive radical formation. It will also reduce energy consumption in comparison with conventional coal gasification process. Irradiation time and steam flowrate were prominent variables in this research. Experimental result showed that 70% syngas was yielded for 6 minutes of microwave irradiation time and 2 L min^{-1} steam flowrate which H_2/CO is 1.8 – 2.2.

Keywords: gasification, microwave, free radical, lignite

INTRODUCTION

The prospect of coal industries for the next decade is promising, since the demand is increasing together with the industrial development due to the growth of the manufacturing industries. It is the most widely used as energy source in electricity generation. World coal consumption is projected to increase from 5.3 billion tons in 2001 to 7.5 billion tons in 2025 (Suyartono, 2006).

As an energy source, coal can be used directly or indirectly by changing its form through conversion process. Direct usage as fuel can have negative impact to environment, especially to the air quality. At present, most power plants in Indonesia and other countries use low quality coal. With a lot of impurities such as ash, volatile matter, etc., steps should be taken to reduce the impact to air quality via conversion technology like carbonization, liquefaction, and gasification. Gasification emerged as a potential solution to convert coal into a valuable gas which has polygeneration utilization (Trap *et al.*). Since almost all gasification reactions are endothermic reactions that require high pressure and temperature, major problem on economic viability of gasification would be from the energy requirement of the process.

The problem calls for the development of non-traditional approach to its solution. Application of microwave technology appeared to be a promising approach. In particular, it is known that the ignition of coal by plasma requires less energy compared to oil or natural gas. This improvement is related to additional crushing of coal particles by plasma, production of free radicals, and acceleration of chemical reactions of coal oxidation (Schunemann, 2002).

A certain experience has been accumulated in the development and application of plasma gasification of pulverized coal in industry. So far this technology is, however, not widely used. The reason for this can be related to shortcomings of the plasma source commonly used in gasifier, i.e. change the plasma generator electrodes. The application of microwave plasma sources looks more promising, because it is operating without the application of special electrodes, and because the microwave energy needed for the plasma initiation can easily be fed to the corresponding site without reconstruction of the gasifier. In this paper, the results of a corresponding study are aimed to understand the influence of irradiation time and steam flowrate to the yield syngas using microwaved steam.

MATERIALS AND METHODS

Materials

Lignite from South Sumatra was used as reactant material (Table 1). The sample was sieved through 60 mesh then pre-heated at 130°C to vaporize the volatile matter and moisture content for about 60 minutes. The dried lignite was then weighed 100 gr.

Table 1. Proximate Analysis of Lignite

Fixed carbon (wt%)	Inherent moisture (wt%)	Volatile matter (wt%)	Ash (wt%)
37.95	14.56	43.57	3.92

Methods

The experimental apparatus for lignite conversion using steam microwave plasma is shown in Figure 1. The reactor was connected to a part of microwave apparatus that we called microwave waveguide for feeding steam plasma, pass through a quartz tube of 25.0 mm inside diameter and 100 mm length. The dried coal (100 grams) was set in the middle of reactor. Pure oxygen was injected to reactor through gas distributor.

Microwavs of 2.45 GHz, with desired power level controlled by a waveguide tuner, were irradiated into passing steam. The flow rate of steam was varied from 1 L min^{-1} to 2.5 L min^{-1} and irradiation time from 2 to 8 minutes. Outlet reactor was connected to a cyclone, and centrifugal force was used to separate the solid particles such as ash, unreacted coal from crude syngas. Water acts as a coolant inside cyclone. The molecular sieves separator was used to separate syngas from water in the gaseous product and other impurities. Several cyclone output streamline was collected in water tank. A gas sampling was used to collect gas from sampling points in molecular sieve separator output streamline. Gas product was analyzed in SHIMADZU Gas Chromatograph GC-8A.

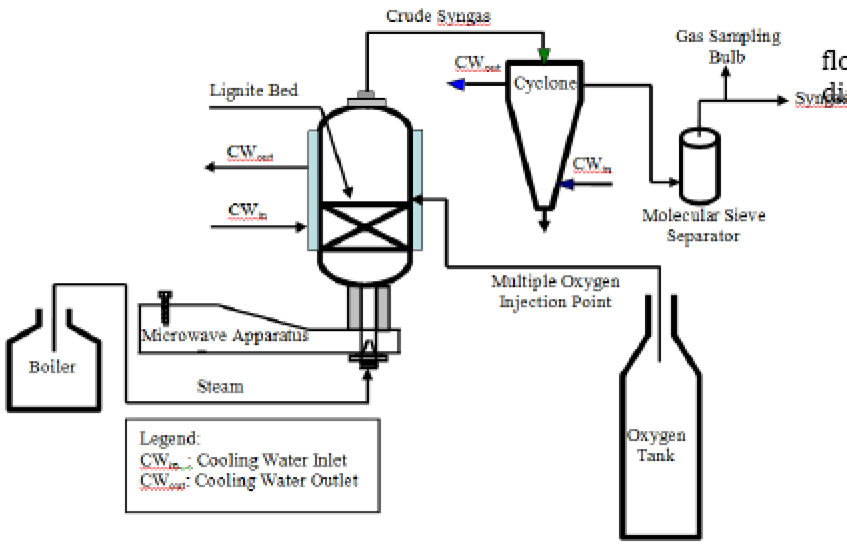

Figure 1. Experimental Diagram Set Up

However, yield of hydrogen near linier with the highest steam flowrate for a given value of ν (steam flow) due to swirl disturbance.

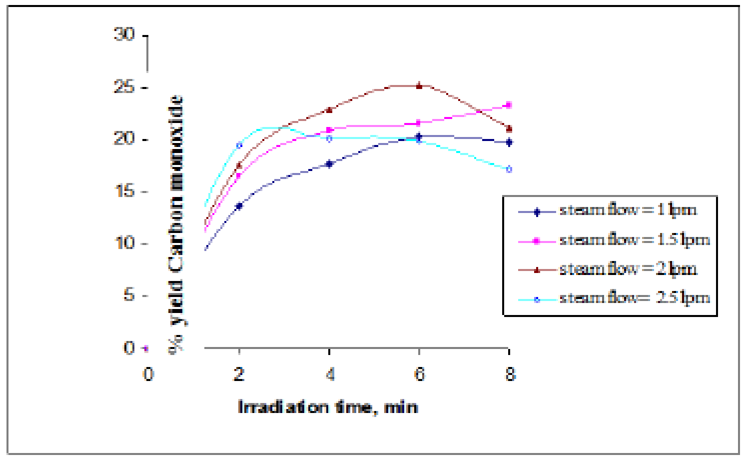

Figure 3. Graphic of steam flowrate and irradiation time effect on yield CO percentages

RESULTS AND DISCUSSION

The potential applications of microwave in gasification are arranged by radical properties, and therefore by the molecular steam excitation. This experiment was carried out to study the effect of steam flowrate and irradiation time increment towards syngas yield in order to estimate the possible advantage from the implementation of microwave gasifier in lignite gasification.

Effect of Irradiation Time and Steam Flowrate on Yield of Hydrogen and Carbon Monoxide

The effect of τ (irradiation time) is studied for ν (steam flow) at 1, 1.5, 2, and 2.5 L min^{-1}. When the microwave was turned off, there was no noticeable syngas produced. Figures 2 and 3 showed the change of in hydrogen and carbon monoxide yields by varying microwave irradiation time with radical generation. Depicts from Figure 2, yield of hydrogen increased with increase of irradiation time. This result indicated that dissociation rate of steam increased in proportion to the irradiation time. The yield of hydrogen showed a maximum value of 44.76% at 6 minutes of irradiation.

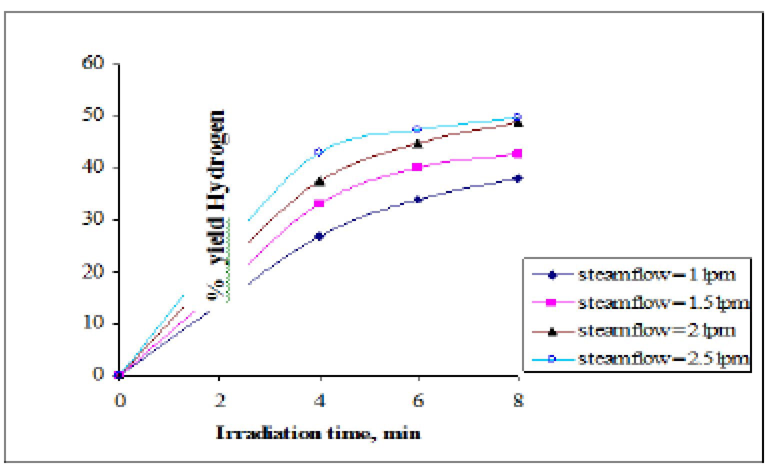

Figure 2. Graphic of steam flowrate and irradiation time effect on yield H_2 percentages

Whatever the flowrate steam and irradiation time values, H_2 mainly produced rather than CO. Figure 3 showed maximum value of 25.24% at 2 L min^{-1} steam flowrate for 6 minutes of irradiation. The increase of irradiation time had significant effect on yield at steam flowrate 1.5 L min. However, the increase of flowrate resulted on decreasing yield carbon monoxide. Swirl disturbance of microwaved steam strongly decreased carbon monoxide percentage. Due to radical generation disturbed by steam flow where as steam can not absorb microwave energy effectively.

CONCLUSIONS

In addition to radical formation of steam and derivation of energy activity as a non thermal effect of microwave utilizing, microwave dielectric heating supply energy for gasification reactions. The present study showed that irradiation time and steam flowrate in lignite gasification process were plays big roles in increasing yield syngas percentages. Swirl disturbance acts as the most important factor in radical formation by microwave. In this experiment maximum value yield syngas of 70%, at steam flowrate 2 L min^{-1} and 6 min of microwave irradiation.

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