Carbon Emissions Of Palm Shell Combustion In Fluidized Bed

Rosyida Permatasari, MNM Jaafar

Abstract : The emissions from FBC (Fluidized Bed Combustion) are dependent on temperature, staged air, excess air, fuel feed rate and fuel properties. In this paper therefore, an accurate report of the experimental results taken in a staged air fluidized bed combustion scale is given. It is important to note that during the experiment, palm shell was used as fuel and silica sand as inert material. The silica sand was used to ensure sustainable combustion in FBC while changing of fuel feeding rate was carried out successfully by modifying the rotation of Miki pulley with time. Furthermore, the amount of partial changes in excess and secondary air were obtained through measurement. The gaseous emissions of CO and CO_2 concentrations were measured using TOCSIN 320 gas analyzer while the temperatures along the combustor height and the flue gas were obtained using the K-type thermocouples. According to the results obtained, 0% and 60%EA at 40%SA is the most favorable condition when trying to reduce CO emission. However, increasing of air staging level will reduce the CO2 concentration at 60%EA.

Index Terms: Fluidized bed, Staged air, Palm shell, Excess air, Fuel feeding rate, CO emission, CO2 emission,

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1. INTRODUCTION

Fossil fuels continue to dominate the global energy usage even though there is also significant expansion in the utilization of renewable energy sources and electricity generation. In the usage of energy globally, developing countries seem to be consuming the most energy. This increase in demand for energy has led to many environmental, economic and institutional problems which include: depletion of fossil fuel resources, uncertainties of energy prices and availability, significant climate changes due to greenhouse gas emissions from energy generation, increase in local and region pollution due to acid rains and ozone layer depletion. It is quite difficult to efficiently meet the increasing need for energy without noticeable environmental impact. To overcome this challenge, cleaner and newer energy conversion systems need to be implemented. It is unfortunate to note that the increased concentration of greenhouses in the atmosphere, especially CO2, is having a negative effect on the Earth's climate. Based on the Kyoto protocol, where the international community agreed on binding emission targets, developed countries have taken it upon themselves as a responsibility, to reduce their greenhouse emissions. The first step they have taken to make this possible is the increased use of biomass in energy systems [1-2]. The Asian Regional Research in Energy, Environment and Climate Phase II (ARRPEC-II) recently conducted a study which showed that biogas would be the most important energy resource in terms of economic and technical feasibility in the next few decades [3-4]. This important energy resource is one of the several renewable energy sources available on earth. and residues from agriculture including vegetable and animal substances, forestry and related industries. Due to the abundance of palm oil planting areas in Asian countries such as in Malaysia, Thailand, Vietnam and Indonesia, biomass residues from palm oil would be of great value in the future [5]. Air pollutants like CO, CO_2, NO_x, SO_2 and particulate matter (PM) are the major culprits in the pollution of air. They are formed from the wastes of combustion processes in industries and efforts are being made to reduce those emissions. One of the possible solutions to reducing these harmful emissions is the Fluidized bed technology. This technology has been established for future energy and electricity generation. Currently, it has been used in the chemical and metallurgy industries and most recently in power engineering. Fluidized bed combustion (FBC) is also now known as an eco-friendly technique for burning coal, biomass and wastes [5]. Fluidized Bed Combustion (FBC) is one of the most promising energy conversion options available today. This technology uses a continuous stream of air to create turbulence in a mixed bed of fuel, inert material and coarse fuel ash particles. The whole process of combustion occurs at temperatures between 800 and 900°C. During the process, particles are mixed constantly, thereby leading to rapid heat transfer and complete combustion. The important principles of FBC are fluidization, combustion and emission formation [6]. Furthermore, the method used in this work was air staging with controlling of operating conditions, i.e., temperature and excess air (EA). The calculations for air staging was done by dividing the air supply into in-bed fluidizing primary air and over bed secondary air (SA) and degree of air staging was expressed as the ratio of secondary to total air. Finally, due to the characteristics of air staging, there is a huge reduction in the emissions [6].

2 RESEARCH METHODOLOGY

2.1 Experimental Set Up

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Fig. 1 shows a schematic diagram of the experimental combustor which was constructed from mild steel and is 0.5m in height and 0.36m squared in cross section. Also, the insulated reactor is fabricated from stainless steel cylindrical tube that has an internal diameter of 164mm and height of 2.0m divided into five flanged sections. During the experiment, Silica sand of 0.365mm mean particle diameter and 2500kg/m^3 density was used as the bed material, then air from a blower was introduced into the bed through a distributor with air outlets arrayed around a circular tube in six rows. This was done easily because there are a total of 36 air outlets with 6 outlets in each row of 5 mm diameter each. Finally, reactor preheating was achieved by using auxiliary fuel. Flue gas exits the top of the freeboard and enters into a cyclone [7].

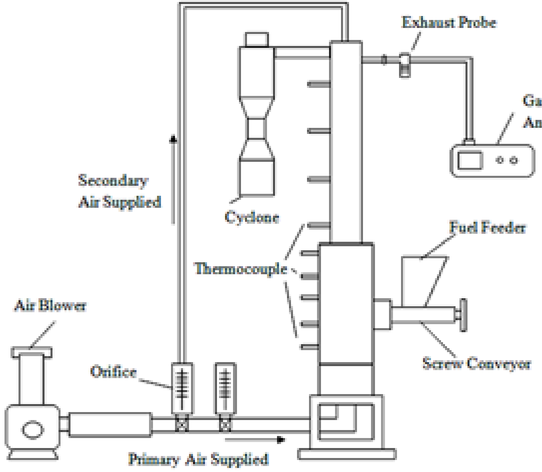

Fig.1. *Schematic diagram of the experimental combustor*

2.2 Experimental Procedure

The pre-heating system was used in heating the inert materials. To carry out this process, the auxiliary flame had to be introduced into the combustion chamber. The feeding of fuel was conducted when the bed temperature was approximately 4500C. It was conducted using a screw type feeder at fuel feed rate of 87.9g/min and then the TOCSIN equipment was used to obtain emission readings. These emission readings were taken when the bed temperature stabilized at approximately 9500C and above. After this, air staging was achieved by dividing the total combustion air supply for stoichiometric operation into primary (in bed fluidizing) and secondary air. The introduction of secondary air was done at 400mmm above the distributor plate with a 9.5mm internal diameter stainless steel tube. In the air staging experiments that were performed, the secondary air to total air ratio varied from 0% to 40% with increments to 10%. Also, excess air varied from. 0% to 60%. Table 1 displays the chemical analysis of palm shell [7].

3 RESULTS AND DISCUSSIONS

3.1 Temperature Distributions

As SA was introduced into the chamber, there was an initial temperature reduction because of the cold air. SA also made the fuel air ratio leaner. Furthermore, the combustion became more active due to extra oxygen. There was also an increase in combustion residence time and this resulted in more complete combustion. This means that the remaining volatiles and unburned carbon would be re-combusted to make the combustion complete. Furthermore, the increased SA helps in reducing temperatures past certain points along the chamber axis. However, whenever the temperature starts to reduce, it is due to depletion of fuel materials.

TABLE 1

CHEMICAL ANALYSIS OF PALM SHELL

Ultimate Analysis	Palm Shell (%)	Proximate Analysis	Palm Shell (%)
C	57.94	Moisture	7.14
H	5.65	Volatile	78.05
O	31.38	Fixed Carbon	17.64
N	0.65	Ash	4.32
Gross CV (HHV) MJ/kg	20.43		

Introducing SA into the chamber initially caused temperature reduction because of the cold air. It made the fuel air ratio leaner and then the combustion became more active due to extra oxygen. It also caused increased combustion residence time, thereby promoting more complete combustion. The increased combustion residence time also means that the remaining volatiles and unburned carbon would be re-combusted to complete the combustion. Thus, reducing temperatures past certain point along the chamber axis, as the SA increased. However, if the temperature starts to reduce at any point, it is due to depletion of fuel materials. All the results at this point is presented in Fig. 2. The figure shows the effect of secondary air ratio on temperature for all EAs at the location. From observations, without SA and EA the temperature recorded was 444ºC. However, with the introduction of EA, the temperature initially increased to a maximum of 566.9ºC for EA20%, then it continues to reduce with the increase of EA to record a temperature of 540 ºC for EA60%

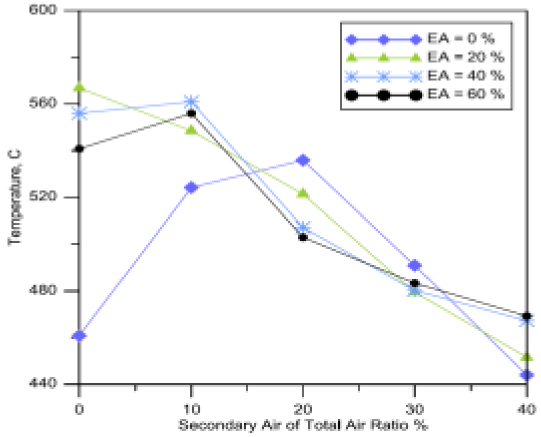

Fig. 2. *Effect of SA on temperature profile for different EA at flue gas*

3.2 CO and CO$_2$ emissions

3.2.1 Effect on CO Emission Concentration

The emission of carbon monoxide (CO) is essentially a result of incomplete combustion. That is why CO is classified as an unburnt pollutant. The experimental results of CO emission with respect to the increase of the EA from 0% to 60% for various SA ratios of 0%, 10%, 20%, 30% and 40% are shown in Fig. 3. According to the results, the SA0% had the highest CO emission of about 10000ppm at EA0%, while the SA40% had the lowest one of about 800ppm. From close observations, it seemed that at EA0%, a high SA value would lead to a larger CO emission. However, this relationship was not linearly proportional. Also, at EA60% the SA0% also had the lowest value of about 190ppm. Finally, the end values of CO emission for SA ratios, which were other than SA40%, were approximately between 1000 and 2000ppm.

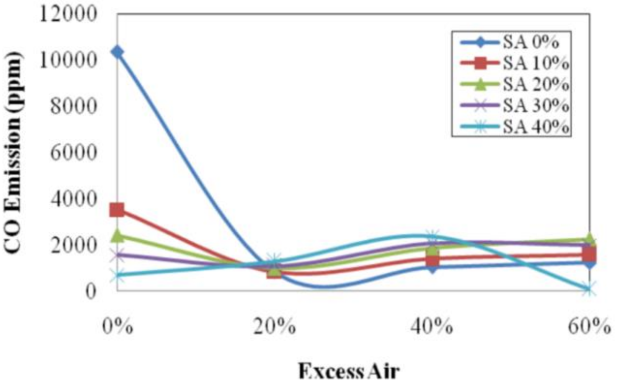

Fig. 3. *Effect of EA on CO emission concentration at different SA*

The experimental results of CO emission with respect to the increase of the SA (SA) from 0% to 40% for various EA (EA) ratios of 0%, 20%, 40% and 60% are shown in Fig. 4. The figure shows that there was a big drop in CO emission for EA0% from SA0% to SA10%, then slowly decreasing from SA10% to SA40%. The CO emission formation is presented by lower EA, restricted residence time, lower temperature and diffusion controlled reactions due to fuel composition (high ash contended). This means that an injection of SA into the bed results in low emission of CO. Other EAs tend to gradually increase the CO emission in which the EA60% was little bit faster than EA40%. Also, the EA60% tends to have a constant CO emission, although there was a little bit increasing at SA40%.

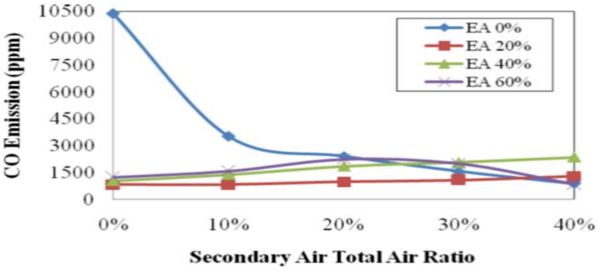

Fig. 4. *Effect of SA on CO emission concentration at different EA*

Therefore, according to the experiment, we could see in these figures, the highest EA and SA (EA60% and SA40%) gave the lowest CO emission of 1139ppm.

3.2.2 Effect on CO_2 Emission Concentration

The experimental results of CO_2 emission with respect to the increase of the EA (EA) from 0% to 60% for various SA (SA) ratios of 0%, 10%, 20%, 30% and 40% are shown in Fig. 5. SA0% and SA40% both shows decreasing trends of CO_2 emission. Also, for the SA0%, the CO_2 emission decreases at a constant rate from about 14% at EA0% to 6.5% at EA60%. The SA40% was the only SA ratio which shows its final value decreasing from about 10% at EA20% to about 5% at EA60%. Both SA20% and SA30% had similar trends, but the SA20% show higher value than the SA0%. As a result of the similarity, their CO_2 emission peaks took place at EA20%. The smallest increase of CO_2 emission for about 2% was experienced by SA10% which tops out at about 13%.The experimental results of CO_2 emission with respect to the increase of the SA (SA) from 0% to 40% for various EA (EA) ratios of 0%, 20%, 40% and 60% are shown in Fig. 5. When observed closely, it could be seen that there was a significant drop in CO_2 emission for EA0% from about 14.4% at SA0% to about 4% at SA30%, then increasing again to 10% at SA40%. The EA40% shows initial CO_2 emission of 9%. It had a CO_2 emission peak of about 13% at SA10%, and then slowly decreased to 7% at SA40%. Also, the EA60% shows initial CO_2 emission of 7%. It displays a CO_2 emission peak of about 10% at SA10%, and then slowly decreased to 5% at SA40%. The EA20% tends to produce a fluctuating CO_2 emission around 10.5%. Its lowest value was about 9% at SA10% and highest value was about 13.3% at SA20%.

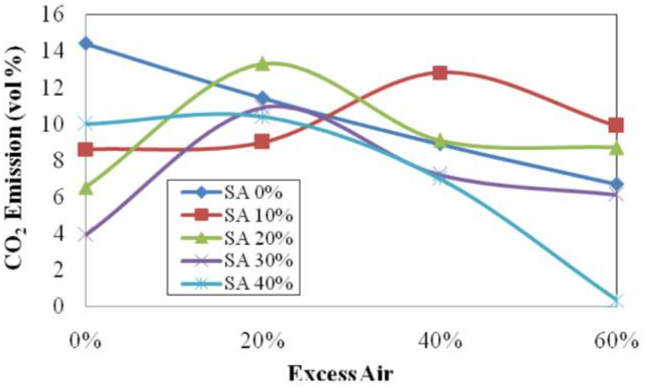

Fig. 5. *Effect of EA on CO_2 emission concentration at different SA*

As seen in Fig. 6, the highest EA and SA (EA60% and SA40%) produced the lowest CO_2 emission of 5%vol, due to the lowest CO emission in the same condition. From observations, as CO emission decreased, the O2 level increased. This means that the presence of air staging helps in completing the oxidation of carbon monoxide (CO) to carbon dioxide (CO_2). However, the increase in O_2 concentration caused CO to be converted to CO_2. This can clearly be seen in the principal reactions for the combustion of the fuel: $2CO + O_2 \rightarrow 2CO_2$. According to Rosyida Permatasari, the concentration of CO2 for palm shell is lower than that of palm fiber. Also, the CO concentration for palm shell is lower when compared to that of palm fiber [7].

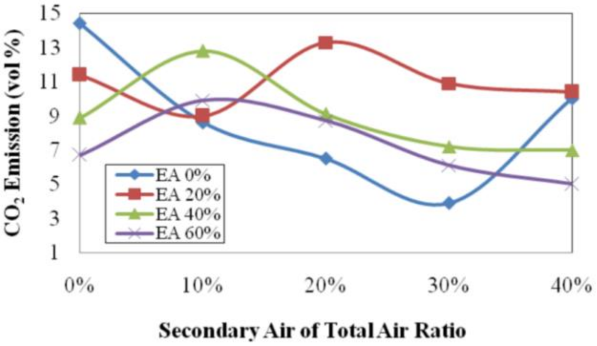

Fig. 6. *Effect of SA on CO2 emission concentration at different EA*

4 CONCLUSION

According to the results, the optimum condition for CO reduction purposes is 0% and 60%EA at 40%SA. Also, it was established that increasing of air staging level will decrease CO2 concentration at 60%EA and the introduction of SA could assist in completing the oxidation of CO in the flue gas.

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