# Combustion Characteristics of Palm Wastes in Fluidized Bed Combustion

Rosyida Permatasari, Kang Kin Hui, Mohammad Nazri Mohd. Ja'afar*
Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM
Skudai, Johor, Malaysia
prosyida@yahoo.com, nazri@fkm.utm.my

***Abstract*-Fluidized bed combustion (FBC) is one of the most promising energy conversion options available today. The emissions from FBC are very dependent on a number of operating conditions (temperature, staged air, excess air, fuel feed rate, etc.) and fuel properties. This paper described the experimental results taken in a staged air fluidized bed combustion scale laboratory, using palm shell and palm fiber as fuels and silica sand as the inert bed material. The silica sand was used for ensuring sustainable fuel ignition and combustion in FBC. The variation of excess air and fuel feeding rate were taken in these experiments. Gaseous emissions of CO concentrations, combustion efficiency and temperature along the combustor height as well as in flue gas were measured in the experimental tests. The experimental results showed that the axial temperature profiles decrease successively related along the FBC height. The CO emission obtained results lower for staged air condition than for un-staged air condition. And the combustion efficiencies give satisfied value. The palm wastes combustion give significant contribution for reduction of CO emission from combustion process.**

## I. INTRODUCTION

Fluidized Bed Combustion (FBC) is one of the most promising energy conversion options available today. FBC uses a continuous stream of air to create turbulence in a mixed bed of fuel, inert material and coarse fuel ash particles. It occurs at temperatures typically between 800 and 900°C. Constant mixing of particles encourages rapid heat transfer and complete combustion. Fluidization, combustion and emission formation constitute the fundamental issues of FBC.

In order to meet the increasing uses of energy with higher efficiency without significant environmental impact, the development and implementation of newer and cleaner energy conversion system are essential. The increased use of biomass in energy systems is an important strategy to reduce the emissions [1]-[3]. Biomass residues from palm oil are potential usage because of many palm oils planting area in Asian countries, like in Malaysia, Thailand, and Indonesia [4]-[5].

The method used in this work was air staging with controlling of operating conditions, i.e., temperature and excess air (EA). Air staging was achieved by dividing the air supply into in-bed fluidizing primary air and over bed secondary air (SA). Degree of air staging was expressed as the ratio of secondary to total air. Effects of air staging are characterized by the reduction of emissions.

## II. EXPERIMENTAL SET-UP

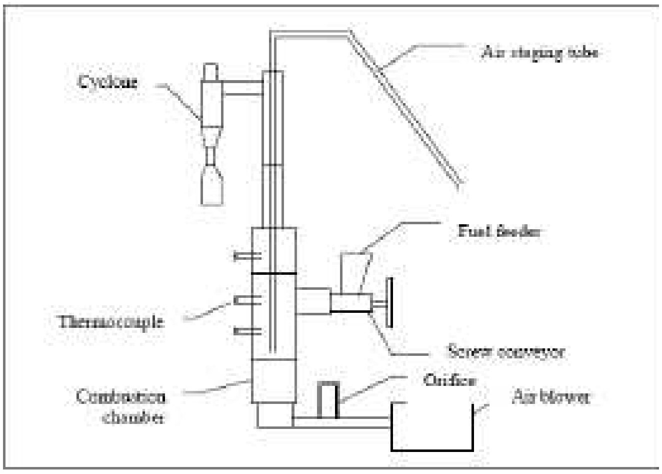


Figure 1. Schematic diagram of the experimental Combustor

Figure 1 shows a schematic diagram of the experimental combustor. The experimental combustor was fabricated from mild steel and is 0.5 m in height and 0.36 m squared in cross section. The insulated reactor is made from stainless steel cylindrical tube of 164 mm internal diameter and 2.0 m height and divided into five flanged sections. Silica sand of 300 μm mean particle diameter was used as the bed material. Air from a blower was introduced into the bed through a distributor with air outlets arrayed around a circular tube in six rows. There are a total of 36 air outlets with 6 outlets in each row of 5 mm diameter each. Reactor preheating was achieved by using auxiliary fuel. Flue gas exits the top of the freeboard and enters into a cyclone.

## III. EXPERIMENTAL PROCEDURE

The task of heating the inert material is fulfilled by the pre-heating system. This was done by introducing the auxiliary flame directly into the combustion chamber. When the bed temperature reaches approximately 450$_0$C, fuel was fed by a screw type feeder at the rate of 79 g/min. Emissions readings were then taken when the bed temperature stabilizes at approximately 950$_0$C and above. Air staging is achieved by dividing the total combustion air supply for stoichiometric operation into the primary air (in bed fluidizing air) and secondary air. Secondary air was introduced at 400 mm above the distributor plate with a 9.55 mm internal diameter stainless steel tube. The air staging experiments were performed with the secondary air to total air ratio varied from 0 to 0.2 at 0.1 increments.

TABLE I
FUEL COMPOSITIONS [8]

| **Type of fuel** | Palm Shell | Palm Fiber |
|---|---|---|
| **Proximate analysis (% by mass)** | | |
| Moisture content | 12.15 | 13.98 |
| Ash content | 1.96 | 3.63 |
| Volatile matter | 79.22 | 84.78 |
| Fixed carbon | 18.82 | 11.59 |
| **Ultimate analysis (% by mass)** | | |
| Carbon, C | 47.978 | 50.091 |
| Oxygen, O | 45.781 | 41.147 |
| Hydrogen, H | 5.487 | 6.247 |
| Nitrogen, N | 0.714 | 2.385 |
| Sulphur, S | 0.04 | 0.13 |
| **Other characteristics** | | |
| Net calorific value (MJ/kg) | 18.84 | 17.64 |
| Gross calorific value (MJ/kg) | 21.44 | 19.6 |

## IV. RESULT AND DISCUSSION

### *4.1. Temperature Distributions*

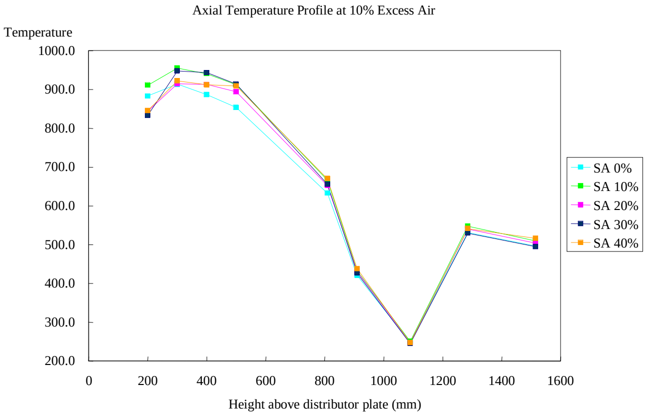


Figure 2. Temperature profile of Palm Shell for 10% Excess Air

Increasing the degree of secondary air tend to decrease temperature distributions along the FBC height, are showed in Fig. 2, 3, 4, 5. Increasing the proportion of secondary air in the combustor reduces flame temperatures and reduced the residence time due to the local air velocity increase which increases particles carry-over and volatiles speed.

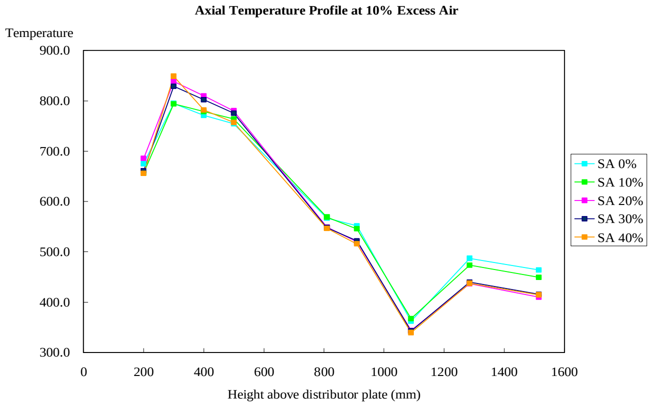


Figure 3. Temperature profile of Palm Fiber for 10% Excess Air

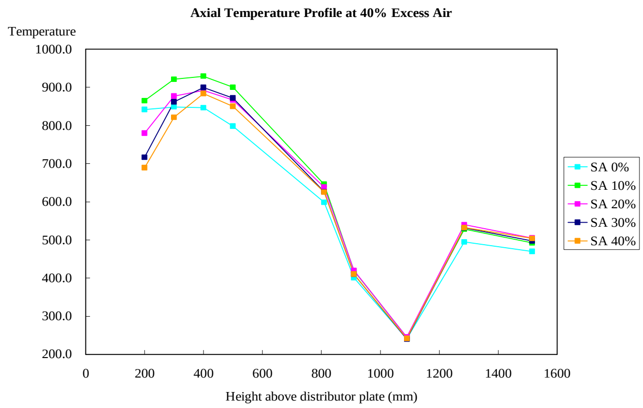


Figure 4. Temperature profile of Palm Shell for 40% Excess Air

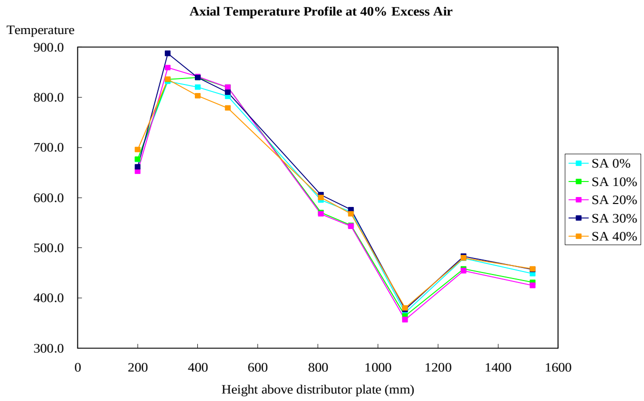


Figure 5. Temperature profile of Palm Fiber for 40% Excess Air

### *4.2. CO Emission*

Figures 6, 7 show that the CO emission decreases with the increase of the secondary air to total air ratio. For palm shell the emission decreases at 30% secondary air (SA) and for palm fiber the emission decreases and at 20% SA.

Also (has been studied) the effect of excess air (EA) on formation and reduction of CO in a Fluidized-bed Combustor Fired with Thai Rice Husk, that CO emission decreases with increasing excess air.

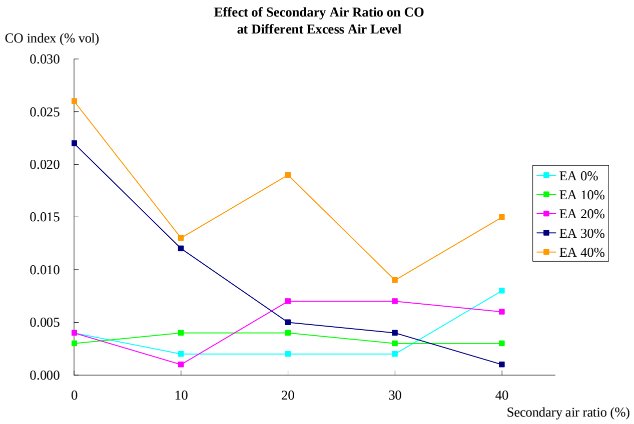


Fig.6. Effect Secondary Air Ratio on CO Emission of Palm Shell

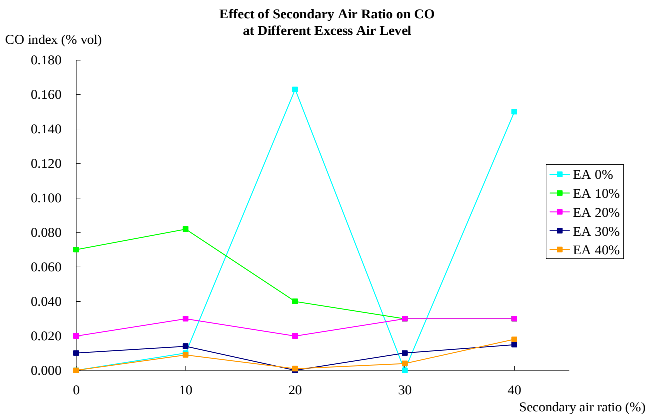


Fig7. Effect Secondary Air Ratio on CO Emission of Palm Fiber

### *4.3. Combustion Efficiency*

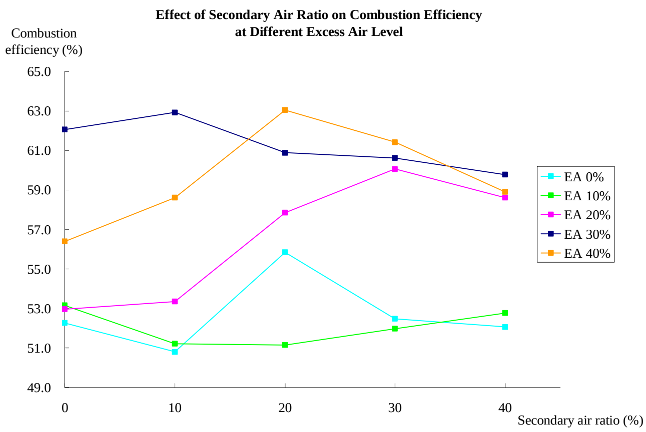


Fig.8. Effect Secondary Air Ratio on Combustion Efficiency of Palm Shell

From the results of our experiments, it was also observed that increasing the degree of air staging has the effect of increasing the combustion efficiency, especially for SA 20% of EA 20%, 30% and 40%, shown in Figure 8 and 9.

The combustion efficiency maximum for palm shell is 63% and for palm fiber is 89%.

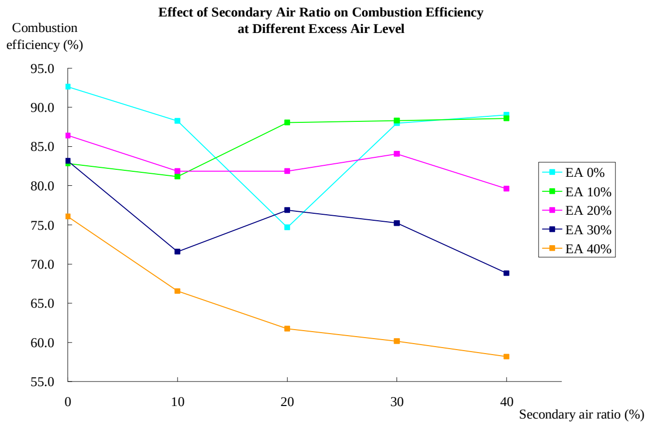


Fig.9. Effect Secondary Air Ratio on Combustion Efficiency of Palm Fiber

## V. CONCLUSIONS

Experiments on the combustion of palm shell and palm fiber have been successfully carried out in a laboratory scale fluidized bed combustor using the air staging technique. The following conclusions can be drawn.

- The axial temperature profiles decrease along the FBC height.
- The use of air staging is beneficial for the reduction of CO emission from a fluidized bed combustor.
- The combustion efficiency is also seen to increase with increased air staging.
- The palm wastes combustion give significant contribution for reduction of CO emission from combustion process.

## ACKNOWLEDGMENT

We gratefully acknowledged the financial assistance from Institutional Grant Universiti Teknologi Malaysia.

## REFERENCES

[1] Wahlund, Bertil. “Rational Bioenergy Utilisation in Energy Systems and Impacts on $CO_2$ Emissions”. *Doctoral Thesis. Department of Chemical Engineering and Technology Energy Processes*, Royal Institute of Technology, 2003.

[2] Nussbaumer T. “Combustion and Co-combustion of Biomass”. *12th European Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection*. June 17-12, Amsterdam, 2002.

[3] Slupek S., M. Poskart, L. Szecowka. “Reduction of $NO_x$ in Natural Gas Flame using Biomass as Reburning Fuel”. *The seventh Asia-PacificInternational Symposium and energy Utilization*, December 15-17, Hong Kong SAR, 2004.

[4] Prasertsan, S. and Prasertsan, P. “Biomass Residues from Palm Oil Mills in Thailand: An Overview on Quantity and Potential Usage.” *Biomass andBioenergy*, 1996, 11(5), pp 387-395.

[5] Barlow, C., Zen, Z., and Gondowarsito, R. "The Indonesian Oil Palm Industry". *International Oil Palm Study Group*, 2003.

[6] Kaewklum, R, et al., "Influence of Fuel-moisture Contentand Excess Air on Formation and Reduction of CO and NO in a Fluidized-bed Combustor Fired with Thai Rice Husk", *Proceeding of The 2nd Joint International Conference on "Sustainable Energy and Environment (SEE 2006*)", 21-23 November, Bangkok, Thailand , 2006.

[7] Gibbs, B.M., Pereira, F.J. and Beer, J.M, "The Influence of Air Staging On the 'NO' Emission from a Fluidised Bed Coal Combustor". *Chemical Engineering and Fuel Technology Department*, University of Sheffield, England,1999

[8] M.R. Taib, L.S. Yang, S.L.Yat Seong, "Palm Wastes Combustion in Bubbling Fluidized Bed". Article, Perpustakaan Sultanah Zanariah, UTM, Malaysia, 2002.