

# Development of a high yield and low cycle time biomass char production system

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## Abstract

A prototype of biomass char production system with the potential of high charcoal/fixed carbon yield and low cycle time is developed in the current study. The prototype biomass char production system comprises of a solid biomass heat conversion unit, a carbonizer and a connecting pipe. The heat conversion unit is an updraft fixed bed gasifier with an embedded combustor fueled by solid biomass for generating high temperature flue gas. The carbonizer is a variation of Brazilian beehive charcoal kiln. The connecting pipe transports the hot and oxygen free flue gas from the gasifier to the carbonizer. The flue gas is radially distributed in the floor of the Brazilian beehive kiln through many small openings on the surface of a ring pipe.

In the current study the syngas generated from the updraft fixed bed gasifier is fully burnt in the embedded combustor. This design results in very high temperature and virtually oxygen free flue gas from solid biomass. The hot and reductive flue gas is forced to circulate in the kiln to carbonize the biomass charge. Temperature distribution in the carbonizer is found to be much more uniform than any conventional charcoal kiln. Higher final carbonization temperature in the kiln is also realizable without the sacrifice of any charge in the current approach. All the solid biomass in the kiln is converted into high quality charcoal with very high fixed carbon percentage and solid biomass burnt to ash is barely discernable. The biomass char yield gradually increases by more than 15 percentage points. The carbonization time is effectively reduced to 4 h compared favorably with the conventional 160 h.

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*Keywords:* Charcoal; Biomass; Updraft fixed bed gasifier; Brazilian beehive kiln

## 1. Introduction

Charcoal production is an ancient art. It has been known since the Bronze Age, and was vital to the smelting of metal ores until the discovery of the conversion of coal to coke at the beginning of the 18th century. Brazil, now the largest charcoal producer of the world, with more than 12 million metric tons in year 2002 [1], has preserved its charcoal based industries in large part because it has extensive iron deposits and very few coal mines. However, more and more manufacturers abandon charcoal as a reducer for pig-iron production and convert to coal derived coke due to its low price.

However the Kyoto Protocol and its flexibility mechanisms have rekindled the global attention on the forest as sources of

economic development and environmental service. Carbon sequestration projects aim to generate carbon credits based on Article 12 of the Clean Development Mechanism (CDM) of the Kyoto Protocol benefiting their executors, their financiers, as well as people globally [2]. The financial benefit of coal over biomass char can potentially be reversed if the biomass char induced carbon sequestration credit can be transformed into commodity future and traded freely in the future market [3].

Since biomass char contains virtually trace sulfur or mercury, Norwegian ferrosilicon industry pays \$440 per ton (fixed carbon) for imported wood charcoal [4], when it can obtain coal derived coke at only \$140~\$270 per ton (fixed carbon). Biomass char is also low in nitrogen and low in ash when compared to coal charcoal.

The transformation of biomass to charcoal involves the loss of 60% or more of the substrate's mass with the evolution of nearly 4 mol of gas per mole of monomer. During this

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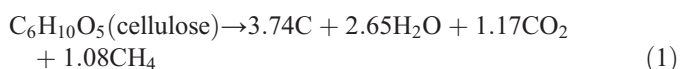
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transformation, the molecular framework of the sugar moieties composing biomass is grossly rearranged to form aromatic structures. Because the transformation does not involve a liquid phase, many bonds are left dangling, giving rise to a carbonaceous solid that is inherently porous at the molecular level and highly reactive.

The purity and reactivity of charcoal enable it to command a premium price as a metallurgical reductant. Other properties cause charcoal to find applications in a surprisingly wide range of fields. Because of their inherent porosity, biocarbons manufactured from charcoal often have high surface areas. These carbons are preferred adsorbents for air and water treatment [5]. In contrast with other renewable fuels like hydrogen and ethanol, charcoal is easy to store and cheap to produce. Similarly, when compared with other conventional fuels, biocarbons are surprisingly benign.

Even though the charcoal production has dated back as early as 4500 BC, the charcoal production technology remains fairly inefficient [6]. The usual industrial technologies for producing charcoal realize charcoal yield in the range of 8% to 25% in the final carbonization temperature of about 500 °C [7]. The cycle to produce a batch of charcoal usually takes about 7 days of heating and 5 to 7 days of cooling. The low efficiency of conventional charcoal production causes the deforestation of many tropical countries and contributes to global warming. In order to make biomass char viable for carbon sequestration purpose, more efficient and cost competitive charcoal production system is needed.

Cellulose is a major constituent of solid biomass. Thermochemical equilibrium analysis of cellulose pyrolysis at constant pressure (1 MPa) can be approximated by the following stoichiometric equation:



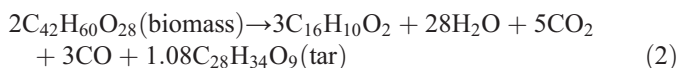
In this equation, the yield of carbon from cellulose is 27.7% by weight. This yield represents that 62.4 % by mole of cellulose carbon is transformed into carbon. No carbon yield converted from biomass has been found that exceeded the theoretical thermochemical equilibrium limit [4].

Charcoals are made in various kinds of carbonization kilns. Earth mound kiln dominates small-scale production and brick kilns are adopted in large-scale production. The Brazilian beehive kiln, the Argentine half-orange kiln, and the Missouri kiln burnt part of the wood charge within the kiln to carbonize the remainder [7]. However, Schwartz kiln uses the hot flue gases from an external incinerator, passed through the kiln to supply heat for drying and heating the wood to start carbonization [7,8]. Long carbonization times (a few days to a few weeks), poor process control, and low charcoal yield are some of the major disadvantages of conventional charcoal making systems.

When biomass is dried and heated to around 280 °C, it begins to spontaneously break down to produce charcoal plus water vapor, methanol, acetic acid and more complex chemicals, chiefly in the form of tars and non-condensable gas consisting mainly of hydrogen, carbon monoxide and

carbon dioxide. The spontaneous breakdown or carbonization of the biomass above a temperature of 280 °C liberates energy and this reaction is therefore exothermic. This process of spontaneous breakdown or carbonization continues until only the carbonized residue called charcoal remains. If external heat is not provided, the biomass carbonization process stops as the temperature reaches a maximum of about 400 °C. This charcoal, however, will still contain appreciable amounts of tarry residue, together with the ash of the original biomass. The ash content of the charcoal is about 4–6%; the tarry residue may amount to about 30% by weight and the balance is fixed carbon about 65–70%. Further heating to the temperature of 500 °C gives a typical fixed carbon content of about 85% and a volatile content of about 10%.

Pyrolysis abruptly transforms wood into a tarry vapor containing a complex soup of organic compounds mixed with noncondensable gases (including CO<sub>2</sub>, CO, H<sub>2</sub>, CH<sub>4</sub>, and heavier hydrocarbons) between 250 and 400 °C. The tarry vapors quickly escape the heated region of the reactor without establishing equilibrium and without forming charcoal. The following equation approximates stoichiometric reaction for the carbonization of wood at 400 °C [8]



The yield of charcoal (C<sub>16</sub>H<sub>10</sub>O<sub>2</sub>) in Eq. (2) is 36.7%, and so that the tarry vapors (C<sub>28</sub>H<sub>34</sub>O<sub>9</sub>) constitute a significant loss of carbon. Because the cost of the wood feed stock comprises 50% or more of the cost of producing charcoal in a conventional kiln, there is great economic incentive to transform these tarry vapors into charcoal and thereby reduce the consumption of biomass. Moreover, a high carbonization efficiency reduces the amount of feedstock consumed, the transportation costs of the feedstock to the kiln, and the release of the tarry vapors into the environment with their serious impacts on air and water quality.

Charcoal yield is closely related to the effects of the gas flow environment in the carbonizer. The manipulation of pressure, moisture content, and gas flow enables biomass carbonization with fixed-carbon yields that approach or attain the theoretical limit after reaction times of a few tens of minutes. Much of the heat needed to carbonize the feed is released by vigorous, exothermic secondary reactions that reduce the formation of unwanted tars by augmenting the charcoal yield in a well-designed carbonizer.

However, for many charcoal makers, the question of yields is not one to which they give a great deal of attention. Provided the wood is plentiful, the question of labor costs and the length of time taken for carbonization can be far more important. However, the conventional methods provide heat to raise the charge temperature in a very slow manner. The heating rate is controlled by adjusting the air allowed into the kiln. If too much air is allowed in the kiln, intensive combustion would take place and charcoal yield would be significantly reduced.

The conventional earth or brick kiln is easy to construct and can repeatedly be used to carbonize biomass charge for a few years. However, this type of kiln is hard to operate and it has a few shortcomings. Slow carbonization speed, large temperature

discrepancies in the kiln, low charcoal yield and not feasible for producing high quality or high temperature charcoal are the major shortcomings of the conventional charcoal kiln.

Externally providing heat to carbonize biomass inside the kiln has the potential of reaching theoretical fixed carbon yield [8]. However the flue gas entering the kiln should be oxygen free and high in heating rate. Carbonization time could be therefore reduced and charcoal yield could be increased. The flue gas circulating the kiln should also possess high momentum to enhance heat transfer in the kiln and to create a uniform temperature distribution in the kiln. Uniform charcoal quality throughout the kiln will therefore be obtained. Higher final carbonization temperature is therefore more achievable.

The current study attempts to use a modified updraft fixed bed gasifier with embedded combustor to generate high temperature and oxygen free flue gas for biomass carbonization. The modified updraft fixed bed gasifier with embedded combustor can be fed with various kinds of solid biomass. The flue gas generated by the biomass system is high in temperature and momentum but low in pollutions and oxygen free. The carbonizer adopted in the current study is a Brazilian beehive type brick charcoal kiln. The hot flue gas generated from the biomass gasifier is forced into the kiln through a ring pipe located in the bottom floor of the kiln. The technological feasibility of the proposed integration of the heating unit and carbonizer is also evaluated.

## 2. System development

### 2.1. Brazilian beehive brick kiln

Conventional Earth or brick kiln is low in construction cost and reasonably high in charcoal yield if properly operated. In the current study we adopt a Brazilian beehive brick kiln design. A schematic of a Brazilian beehive brick kiln is shown in Fig. 1. The radius of the kiln is about 45 cm and the height of the kiln is about 40 cm. The volume of the kiln is about 0.3 m<sup>3</sup>. The flue gas exit of the carbonizer is located on the center floor. An

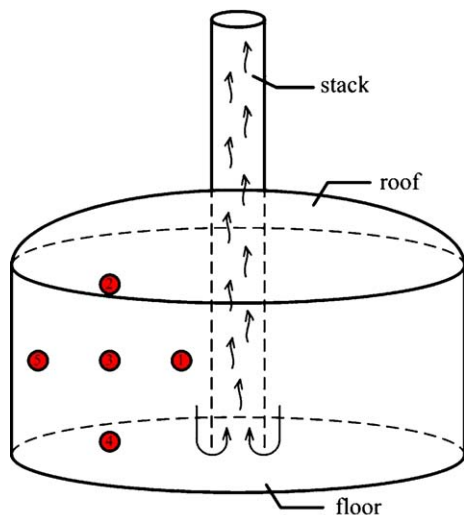


Fig. 1. Schematic of the experimental Brazilian beehive brick kiln.

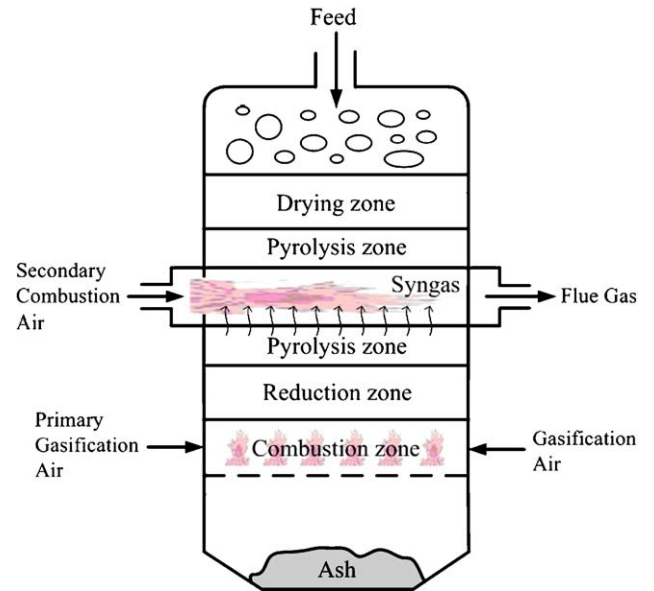


Fig. 2. The schematic diagram of the modified fixed bed gasifier.

extended stack goes from the floor to the roof of the kiln. There is a damper on the stack to control the pressure inside the kiln.

### 2.2. Biomass fed updraft fixed bed gasifier with embedded combustor

Gasification approach is considered more environmentally friendly than the direct combustion or incineration approach in



Fig. 3. Snapshot of the constructed updraft fixed bed gasifier with an embedded combustor.

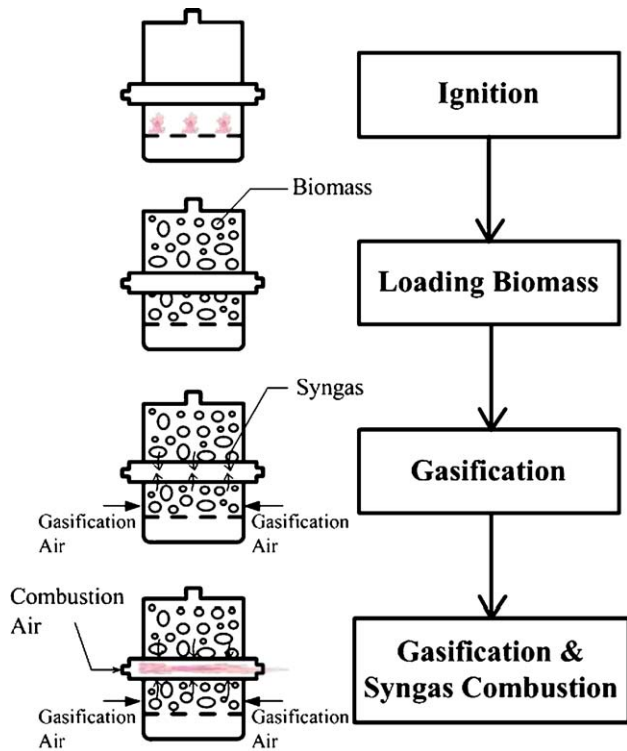


Fig. 4. Operation process of the gasifier.

The schematic diagram of the modified fixed bed gasifier used by the current study is shown in the Fig. 2. Fig. 2 indicates that biomass is fed at the top of the cylindrical reactor, and a grate at the bottom of the reactor supports the reacting bed. Gasification air is introduced radially through numerous small holes on a horizontal ring that is located on top of the grate along the gasifier's inside wall. The syngas produced is forced to squeeze in an embedded tube through many small openings on the lower half of the tube. The embedded tube inside the updraft gasifier serves two purposes: a conduit of the syngas to exit the reactor and a syngas combustor by introducing secondary combustion air to fully oxidize the syngas and release clean and hot flue gas for heat and power application.

The biomass feed moves in counter current to the gas flow, and passes through the drying zone, the pyrolysis zone, the reduction zone and the combustion zone. In the drying zone the biomass is dried. In the pyrolysis zone the biomass is decomposed in volatile gases and solid char. Pyrolysis and drying are mainly delivered by the upward flowing syngas and partly by radiation from the combustion zone. In the reduction zone many reactions occur involving char, carbon dioxide and water vapor, in which carbon is converted and carbon monoxide and hydrogen are produced as the main constituents of the syngas. In the combustion zone the remaining char is combusted providing the heat, the carbon dioxide and water vapor for the reactions involved in the reduction zone.

The embedded combustor is a unique feature of the system. The combustor provides a space to directly combust the syngas inside the gasifier. While intensive combustion takes place in the tube, high temperature is resulted and maintained in the gasifier's pyrolysis zones as shown in Fig. 2. The creation of a high temperature pyrolysis zone increases the overall gasification intensity, and also will result in a much more stable gasification process.

A 150 kW<sub>th</sub> experimental gasifier was constructed for this study. Assuming the gasification intensity is at 100 kg/h·m<sup>2</sup> and biomass's low heating value at 3500 kcal/kg. The bed area could

converting solid biomass into energy. However, all gasification methods produce highly viscous and very tarry acid and dioxins. The produced tars are hard to transport and cause serious clogging and corrosion of the piping. The syngas is therefore very difficult to be stored or utilized without removing tars. Complex de-tar process becomes necessary component for any type of gasification system. This study utilizes a newly designed updraft fixed bed gasifier which combusts the syngas inside the reactor and avoids the whole de-tar process completely.

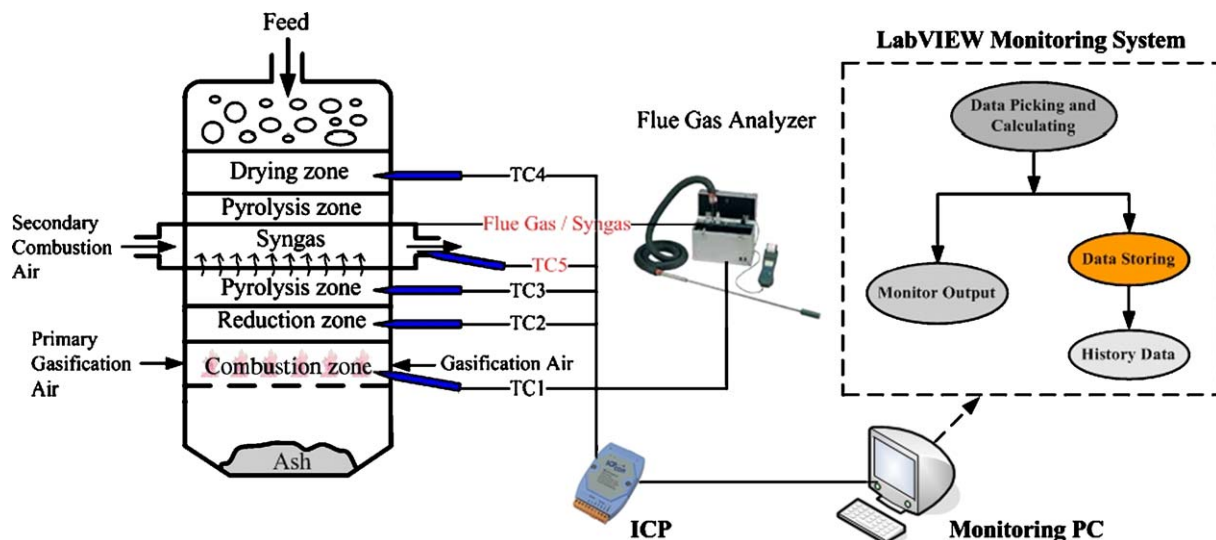


Fig. 5. Schematic of experimental setup.

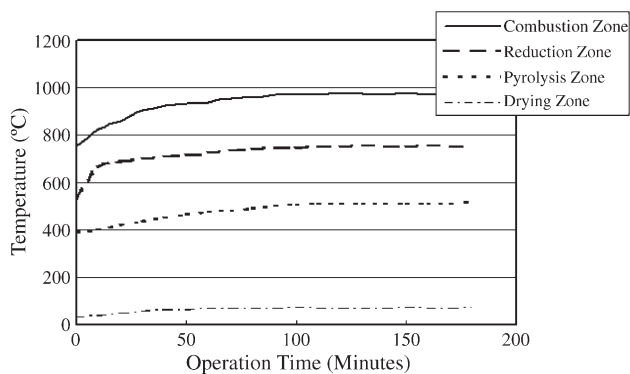


Fig. 6. Temperature distribution inside gasifier.

be calculated to be 0.465 m<sup>2</sup> with a biomass to energy conversion efficiency at 80%. The gasifier volume is designed to hold enough biomass to run for at least 3 h without refueling. Located at a distance of 47.5 cm above the grate, the embedded combustor is fixed and sealed in the gasifier with flanges. The diameter of the combustion tube is 16 cm with numerous tiny openings at the lower half of the tube.

Fig. 3 is the snapshot of the updraft fixed bed gasifier with an embedded combustor. The gasification air and secondary combustion air are provided by a 5 Hp high pressure blower manufactured by North America Inc. This blower could generate 35 m<sup>3</sup>/min airflow rates at pressure 350 mmAq. The high-pressure air is a must in this gasifier with embedded combustor combination for overcoming the high resistance existed throughout the gasifier.

The operation process of the current gasifier is shown in Fig. 4. Starting the gasifier by igniting a small quantity of biomass outside the gasifier and then throwing in the combusting biomass and turn on the gasification air to complete the ignition step. The second step is to feed gasifier the biomass from the top inlet until the gasifier is full of the biomass and then close the top lid to start the gasification step. In less than 15 min or when the syngas temperature reaches about 300 °C in the combustor, air is introduced into the inlet of the combustor and the syngas will self ignite and combust in the combustor. The biomass flows smoothly toward the



Fig. 7. Photo of the combustion flame in the embedded combustor.

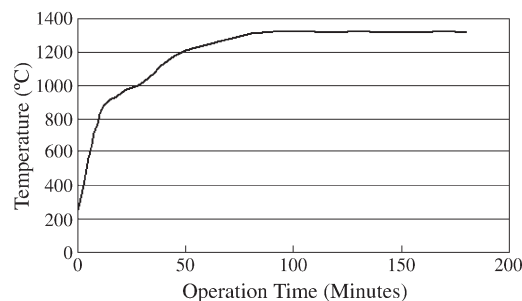


Fig. 8. Represented flame temperature history at the exit of the embedded combustor.

grate and the combustor can maintain its stable combustion of the syngas without needing any assisting fuel throughout the whole process. The modified updraft fixed bed gasifier combusts the biomass generated syngas inside the reactor directly. The heat derived from the direct combustion of the syngas is easy to control through a wide range of air/fuel ratio. The resulted flue gas is high in temperature and momentum but low in pollution and oxygen.

Experimental setup to measure the gasifier's performance is shown in Fig. 5. Temperatures in the gasifier's combustion zone, reduction zone, pyrolysis zone and drying zone are acquired by inserting K-type thermocouples into the respective zone as shown in Fig. 5. In the embedded combustor's outlet, flue gas's temperature is measured by a R-type thermocouple and flue gas or syngas composition are measured by Eurotron GreenLine 8000 mobile flue gas analyzer. The acquired temperature and composition data are collected, signal transformed, and rerouted to a monitoring server through near and far field ICPs. A monitoring system written by the software Labview is developed and used to view and analyze the measured data.

Detailed measurement is presented here by using pine chips as the feedstock. The low heating value of the pine chip is 4100 kcal/kg and moisture content is 18% by weight. Time history of the temperature distributions in gasifier's combustion zone, reduction zone, pyrolysis zone and drying zone as indicated in Fig. 6.

When secondary combustion air is introduced to the embedded combustor to mix with the entrained syngas with high temperature (more than 500 °C) from the gasifier. An intensive flame will be established and maintained in the tube.

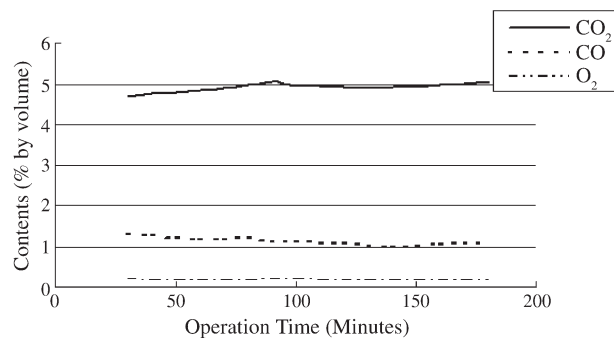


Fig. 9. Flue gas compositions history from the embedded combustor.

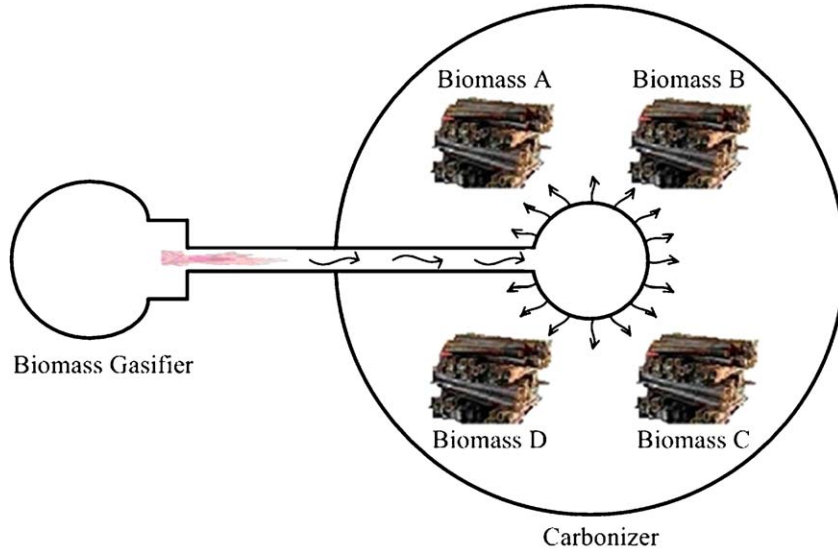


Fig. 10. Integration of a bamboo carbonization kiln with a biomass gasifier.

Fig. 7 is a snapshot of the combustion taking place in the embedded combustor. Time history of the represented flame temperature or flue gas temperature of the tube is recorded in Fig. 8.

As Fig. 8 indicated that this gasifier and embedded combustor combination is capable of producing intensive combustion with flue gas temperature as high as 1320 °C. The flue gas compositions are measured by the Eurotron GreenLine 8000 mobile flue gas analyzer and are shown in Fig. 9. The flue gas composition measurement shows that the flue gas contains about 0.05% of CO, 5% of CO<sub>2</sub> and 0.2% of O<sub>2</sub> by volume. From the measurement results it is clear that the current design is capable of producing clean and very hot flue gas. The stable flame temperature and flue gas compositions as indicated in Figs. 8 and 9 also show the stability and reliability of the current design.

2.3. Connecting pipe and integration strategy

This study conducts biomass carbonization tests in an experimental Brazilian brick kiln. The required heat to initiate biomass carbonization is supplied by a very efficient modified updraft fixed bed biomass gasifier with embedded combustor. The integration of the biomass gasifier and the brick kiln is schematically shown in Fig. 10. The hot and oxygen free flue gas is forced into the kiln floor through a ring pipe. The flue gas squeezes out of the small openings on the ring pipe surface and is evenly distributed inside the kiln. The numerous jets emerge from the ring pipe circulate in the kiln as indicated in Fig. 11. The uniform distribution of the high-speed flue gas into the kiln is expected to create uniform temperature distribution in the kiln.

The snapshot of the final integration of the bamboo carbonization kiln and biomass gasifier is shown in Fig. 12. Biomass is gasified and burned in the gasifier to produce high temperature flue gas. The flue gas is adjusted to be slightly

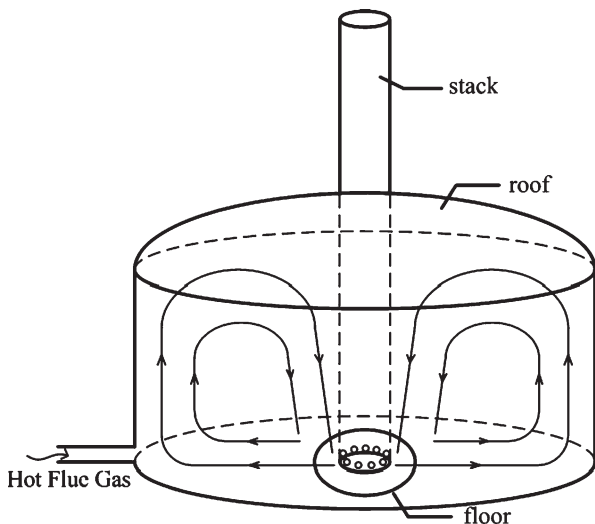


Fig. 11. Schematic of the flow pattern in the carbonizer.



Fig. 12. Integration of the bamboo carbonization kiln and biomass gasifier.



Fig. 13. Biomass gasifier/biomass carbonization system at work.

reductive by using low air/fuel equivalent ratio. The flue gas is injected into the kiln through a ring pipe with diameter of 1.5 in. Fig. 13 is a close up of the system at work. The steel pipe turned into orange color soon after the firing of the gasifier.

### 3. Materials and experiments

#### 3.1. Preparation

*Miscanthus* spp. and *Acacia confusa* Merr. are used in the current experiment to test the performance of the proposed Biomass gasifier/carbonizer system. *A. confusa* Merr. as shown in Fig. 14 are native to southern Taiwan but can now be found throughout Taiwan. *A. confusa* Merr. belongs to hard wood class and has been popular for charcoal purpose. *Miscanthus* spp. as shown in Fig. 15 are perennial C4 grasses, widely distributed in Taiwan. *Miscanthus* spp. are efficient photosynthesis herbaceous crops and can be used as biomass energy source [9]. The two biomass are cut into 35 cm in length and are separately placed in the 0.3 m<sup>3</sup> kiln manually. Figs. 16 and 17 are the snapshots of the two biomass charge in the carbonizer. The gasifier's combustor exit is then connected with the entrance of the kiln's ring pipe to complete the preparation of the experimental setup.

#### 3.2. Measurements

Carbonization in high temperature and reductive atmosphere will produce best quality charcoal. In order to provide high temperature and oxygen free flue gas for biomass carbonization, an Eurotron GreenLine 8000 mobile flue gas analyzer is used to monitor the flue gas exited from the gasifier to ensure oxygen



Fig. 14. *Acacia confusa* Merr.



Fig. 15. *Miscanthus* spp.

free condition is maintained especially in the later stage of the carbonization process when the biomass char temperature is high.

To monitor the transient temperature distribution of the biomass kiln, five K-type thermocouples are placed in the kiln as 5 numbered red points in Fig. 1. During carbonization if the temperature of any monitoring point abruptly increases, local burning is usually the cause and air allowed in the combustor should be reduced.

#### 3.3. Process

After the kiln is hermetically sealed, biomass is fed into the gasifier and high temperature flue gas generated by the gasifier is forced to enter the kiln through the ring distributor. The biomass inside the kiln heated by the hot exhaust goes through de-watering stage (50~120 °C), carbonization stage (250~500 °C), and secondary carbonization stage (600 °C and above). Noticeably the secondary carbonization stage at more elevated temperature is usually not obtainable in the conventional carbonization process. It takes around 2 h for the current design to elevate carbonizer's temperature everywhere to be above 650 °C.

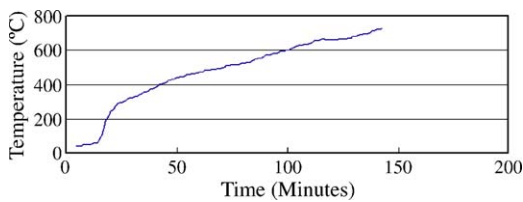
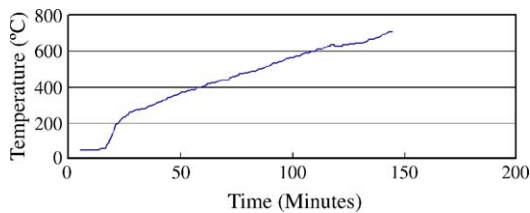
## 4. Results and discussions

#### 4.1. Experimental data

Temperature history at the center of the kiln is shown in Fig. 18 for *A. confusa* Merr. and Fig. 19 for *Miscanthus* spp.



Fig. 16. *Acacia confusa* Merr.

Fig. 17. *Miscanthus* spp.Fig. 21. *Miscanthus* spp. charcoal in the kiln.Fig. 18. History of temperature at the center of the kiln (*Acacia confusa* Merr.).Fig. 19. History of temperature at the center of the kiln (*Miscanthus* spp.).Fig. 20. *Acacia confusa* Merr. charcoal in the kiln.

Since the heating rate of the gasifier is kept fairly constant, the temperature history curve shows flattening down when endothermic reaction like the de-watering process (80~120 °C) is taking place while the temperature history curve will become sloping up when exothermic reaction like primary carbonization (250~450 °C) and secondary carbonization (650 °C and above) is dominating. The temperature history at the other monitoring points in the kiln shows similar carbonization development.

After the kiln is sealed and is naturally cooled for around 1 h, the kiln's temperature drops below 60 °C. The entrance of the kiln is subsequently open for inspection. Figs. 20 and 21 are snapshots taken right after the kiln is open for *A. confusa* Merr. and *Miscanthus* spp. respectively. Closer inspection of the charcoal produced in the current study could not find any sign of intensive burning in the kiln. A total of 24.3 kg of *Miscanthus* spp. charcoal and 11.1 kg of *Miscanthus* spp.

Table 1  
*Acacia confusa* Merr. charcoal sample measurements

	Final temperature (°C)	Fixed carbon rate (%)	Electrical resistivity (Ω-m)
Location 1	718	83.7	195.4
Location 2	698	82.8	200.8
Location 3	730	86.7	163.3
Location 4	738	88.4	159.8
Location 5	717	83.2	197.9

Table 2  
*Miscanthus* spp. charcoal sample measurements

	Final temperature (°C)	Fixed carbon rate (%)	Electrical resistivity (Ω-m)
Location 1	702	92.4	8.7
Location 2	683	91.2	10.2
Location 3	709	93.0	8.4
Location 4	716	94.1	7.6
Location 5	695	92.1	9.1



Table 3  
Overall performance of the current approach and conventional approach

	Conventional approach	Current approach
Time required to heat the kiln to 700 °C	100 h	2 h
Time required to cool the kiln to 60 °C	60 h	1.5 h
Carbonization cycle	160 h=7 days	4 h
Charcoal yield	15~25%	35%
Highest carbonization temperature achievable	800 °C	950 °C
Highest and lowest temperature discrepancy in the kiln	280~350 °C	40 °C

charcoal are produced in the current study. This translates to 36% and 34% charcoal yields for the 67 kg of *A. confusa* Merr. and 32 kg of *Miscanthus* spp. charge loaded in the kiln initially.

Fixed carbon rate (%) and electrical resistance ( $\Omega$ -m) values of the both charcoal in the kiln are determined for the samples taken at 5 positions in the kiln. The measured results are tabulated in Tables 1 and 2. The two measured charcoal attributes show good correlation with carbonization temperature. Electrical resistance of the both charcoals is inversely proportional to the final carbonization temperature. On the other hand fixed carbon rates of the both charcoals are proportional to the final carbonization temperature.

#### 4.2. Overall performance

The overall performance of utilizing a biomass updraft fixed bed gasifier to carbonize *A. confusa* Merr. and *Miscanthus* spp. in a experimental Brazilian beehive brick kiln is tabulated in Table 3. The conventional carbonization approach by burning part of the charge in the carbonizer is also listed in Table 3. The current approach shortens the biomass carbonization time from 100 to 2 h and cooling time from 60 to 1.5 h. Carbonization cycle is dramatically reduced from 7 days to about 4 h. Biomass char yield is also significantly increased from 10~25% to 35%. Higher carbonization temperature achievable without large scale burn off of the charcoal in the current approach is also achievable. Kiln temperature discrepancy improves from about 300 °C in the convention approach to 40 °C in the current approach.

The comparison of the overall performance of the current approach and conventional approach shows the current approach is effective in increasing biomass char yield, shortening carbonization cycle time, and creating a more uniform temperature distribution in a Brazilian beehive kiln. In other words the current approach significantly lowering the conventional biomass carbonization costs and increasing the utilization rate of the biomass charge. The current approach is able to raise the kiln carbonization temperature to more than 900 °C. Higher quality biomass char is therefore more attainable in the current approach.

## 5. Conclusions

A modified updraft fixed bed gasifier with embedded combustor is successfully applied to a Brazilian beehive kiln for biomass char production in the current study. *A. confusa* Merr. (hard wood) and *Miscanthus* spp. (herbaceous crops) are used as to test the current design. Both carbonized biomass demonstrate good functionality and operativity of the proposed integration. The unique feature of the embedded combustor inside the biomass gasifier is shown to produce very clean and very hot flue gas for biomass char production. The experimental results show the newly adopted biomass gasifier/combustor is capable of producing a higher carbonization temperature and more uniform temperature distribution inside the Brazilian beehive kiln and biomass carbonization rate is also much faster than the conventional method. Since the gasifier exhaust is controlled to be oxygen free all time through out the carbonization process, no burn off of the biomass char in the kiln is discernable. The current design therefore has the potential to significantly increase the biomass char yield and lower the cycle time.

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