Performance Gasification

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Performance Gasification Per Batch Rubber Wood in Conventional Updraft Gasifier

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Abstract: Gasification attract smore interest recently since it offers higher conversion efficiency and low pollution generated. Equivalence ratio is parameters for control gasification performance. The purpose of this study is to evaluate gasification rubber wood in conventional updraft gasifier. In this study, the equivalence ratio is varied from 0.21-0.31 according to obtain temperature distribution, gas composition, LHV of the gas, cold gas efficiency and tar content produced. The highest of LHV the gas reachs of 4.2 MJ/m^3 with cold gas efficiency of 73% and tar content of 140 g/m^3 at equivalence ratio of 0.31.

Key words: Gasification, updraft gasifier, woody biomass, equivalency ratio, gas efficiency, Indonesia

INTRODUCTION

Biomass is one of renewable energy that has an advantage available and lower emission of CO_2 (Guo *et al*., 2008; Puig-Arnavat, 2010). Biomass can convert to energy use thermochemical conversion like combustion, gasification and pyrolysis (Kumar *et al*., 2009). Gasification is a chemical process that converts solid carbonaceous material like biomass into combustible gas (gaseous fuel) with dominant component carbon monoxide, hydrogen and methane by limited of air combustion (Basu, 2010). Biomass gasificationhas given more interested compared to combustion and pyrolysis since it gives higher conversion efficiencies (Pratik and Babu, 2009). The application of biomass gasification for generating electricity using gas engines and gas turbines provide higher efficiency compare to steam power systems using biomass fuels in the boiler at capacity <10 MWe (Roch and Kaltschmitt, 1998).

Biomass type and end use of producer gas product are main consideration for selecting of gasifier type (Roa *et al*., 2004). An updraft gasifier is simplest design compare to all type of gasifier where gas and bed of fuel move counter current mode that has achieved high cold gas efficiency (Basu, 2010). The other advantages of updraft gasifeir compare with another type of gasifier are flexible of fuel size, ease of scale upand high moisture content of fuel (up to 60%).

The efficiency of conversion of the gasifier depends on fuel material, air combustion flow rate, particle size and construction of gasifier (Sharma, 2009). The one of parameters for control gasification performance is Equivalence Ratio (ER). The equivalency ratio defined as ratio actual air combustion in a run of combustion process stostockiometric air combustion requirement for the run of combustion process (Jain and Gross, 2000). The theoretical range of equivalency ratio of gasification process is between 0.19-0.43 (Zainal *et al*., 2002; Saravanakumar *et al*., 2007a).

Recently, several biomass gasification process on updraft gasifier have been published (Roch and Kaltschmitt, 1998; Ueki *et al*., 2011; Saravanakumar *et al*., 2007b; Ponzio *et al*., 2006; Khummongkol and Arunlaksadamrong, 1990; Mandl *et al*., 2010; Lucas *et al*., 2003). The combustible gas composition are 20-30% of CO, 4-15% H_2 and 0-2.5% of CH_4. The Lower Heating Value (LHV) of producer gas over 3.5 MJ/Nm^3 with Cold Gas Efficiency (CGE) over 40%. Seggiani have reported co-gasification wood pellet and sewage sludge at variation of equivalence ratio of 0.15-0.25 at updraft gasifier where the result showed the rise of equivalency ratio resulted production more gas almost constant LHV allowing to higher gas efficiency. Roch and Kaltsemitt (1998) have reported gasification wood chip, refused derived fuel and charred soybean straw at constant flow rate. The result showed equivalence ratio between the range 0.35-0.36 with cold gas efficiency between 65-73%. Ponzio *et al*. (2006) studied gasification plastic containing waste in updraft gasifier with equivalency ratio are 0.19, 0.24 and 0.25. The result shows the composition of gas and gas yield at ER of 0.19 have more difference compared to ER of 0.24-0.25.

Several researches use wood as fuel for other gasifier type at condition variation of equivalence ratio on experimental. Pratik and Babu (2009) studied gasification wood on downdraft gasifier with equivalence ratio

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0.262-0.314. the result showed the fraction CO and H_2 increases with equivalence ratio till a value 0.205. Olgun *et al.* (2011) reported gasification wood chip with equivalence ratio 0.2-0.5. The composition of CO primary affected by equivalence ratio with the maximum HHV of the producer gas at equivalence ratio 0.35. Zainal *et al.* (2002) have reported studies on gasification using furniture wood and wood chips where the optimum value of equivalence ratio was 0.38.

This study present characteristic operation per batch gasification rubber wood in updraft gasifier with variation of equivalence ratio.

MATERIALS AND METHODS

Gasifier system: The experimental setup are shown in Fig. 1. The gasifier have made of a stainless steel SUS 304 with an internal diameter of 22 cm and a height of 63 cm. The thickness of stainlessstell is 3 mm. This material has the same with reported by Ueki *et al.* (2011). The both pipe for air inlet and producer gas outlet have a diameter of 5 cm, respectively. The gasifier reactor is covered by ceramic fiber blanket with thickness of 5 cm to prevent heat loss. Biomass is fed from the top of gasifier from window with a diameter of 13 cm. A grate with space interval of 1 cm is used to support charcoal at combustion zone. A window at combustion zone is provided to reside the unburned fuel. This window below combustion zone has the function to remove the ash.

The gasification air is supplied to gasifier using a blower with a maximum capacity of 500 l pm. A control valve is used to set supplying air at constant volume. Air and producer gas flow rate are measured with an orifice differential manometer.

There are 12 ports for crommel-alumnel thermocouple. The lowest one are located at height of 4 cm above of the grate and the others are located at intervals of 5 cm upwards to the top. The temperature is recorded using DAQ. The digital data from DAQ are presented in screen computer using.

The syngas is sampled using sample tight bags from the exit of heated bath and analyzed for its gas composition by gas chromatography with Thermal Conductivity Detector (TCD). The sampling bags must be in vacuum condition before it is used for gas sampling.

Tar component in producer gas is trapped by a series of impinger bottle that filled with acetone as solvent according to guidance (Brage and Sjostrom, 2002; Neefth *et al.*, 2002). The mixture solvent and gas are dried till all solvent evaporated. The remaining tar of producer gas is weighted and measured in g/Nm^3.

Fuel: Table 1 shows the proximate and ultimate analyses and some physical properties of rubber wood. The rubber wood chips have length of 3 cm, width of 3 cm and height of 1.5 cm.

Equation for calculation: The Equivalence Rratio (ER) was calculated as follow according to Zainal *et al.* (2002).

$$ER = \frac{(\text{Flow rate of air supply}) \times (\text{Duration of run})}{(\text{Mass in put of wood}) \times (\frac{A}{F} \text{ for } \phi = 1)} \quad (1)$$

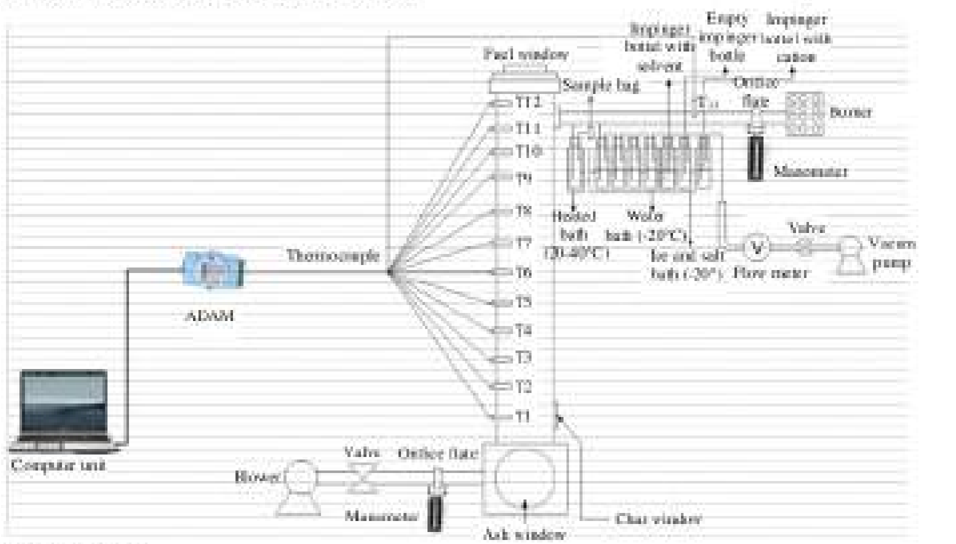

Fig. 1: Experimental set up

Table 1: Proximate and ultimate analysis of rubber wood

Analyses	Units	Values
Proximate		
Moisture (adb)	%	10.24
Ash	%	2.71
Volatile	%	71.80
Fixed carbon	%	15.25
Ultimate		
Carbon	%	43.33
Hydrogen	%	5.11
Nitrogen	%	Not detection
Sulfur	%	Not detection
Oksigen		38.61
Calorific value	Cal g^{-1}	4069
Density	g cm^{-3}	0.64

Where, (A/F) for $\phi = 1$ is 4.44 m^3 of air/kg of rubber wood. The calorific content in producer gas is calculated through the lower heating value of producer which is calculated using following equation according to Seggiani:

$$\text{LHV (kJ/Nm}^3) = y_{CO}\,12621 + y_{H_2}\,10779 + y_{CH_4}\,35874 \quad (2)$$

Where y_i, values are more fractions of main combustible gas in the producer gas. The performance of the gasifieris estimated with cold gas efficiency of gasification where the cold gas efficiency is calculated as follows according to Seggiani:

$$\text{Cold gas efficiency} = \frac{\text{Product gas flow rate} \times \text{LHV}_{gas}}{\text{Wood flow rate} \times \text{LHV}_{wood}}$$

Experimental procedures: The test is commenced by burning 1 kg of rubber wood as biomass fuel, inside the gasification reactor. The fuel is ignited using paper and kerosene over batch of its. After The self sustained combustion has done about 5 min after ignition of fuel, the gasifier filled full and the air flow rate were set to the selected values with air flow rate of 50, 65 and 90 lpm, respectively. Each test uses 6 kg of wood each batch. After the temperature at combustion zone reaches 500°C, the producer gas is ignited. The first gas sampling is taken at 5 min after igniting the producer gas then the next sampling is taken after 20 min operation. The tar sampling is taken after temperature at combustion zone reaches of 700°C. The test is stopped when producer gas flame extinguish it self. The weight of remaining char and ash at combustion zone is measured as well.

RESULTS AND DISCUSSION

Operation characteristics: The time need about ±20 min after start up for produced combustible gas that is indicated in ignition of flare for each air flow rate of 65 and 90 lpm but for the air flow rate of 50 lpm need more long time about 35 min. The combustible gas is produced after temperature at combustion zone is reached 500°C that suitable to reported by Mandl *et al.* (2010). The combustible gas continues produced about 70 min until the process have finished. The number of total waste of charcoal and ash about 7 till 12%, 5% of total wood used where it suitable with reported by Roa *et al.* (2004) using wood chip as fuel. The increasing of air supply will reduce number waste charcoal and ash. The increasing air flow rate will increase fuel consumed and reduce time operation.

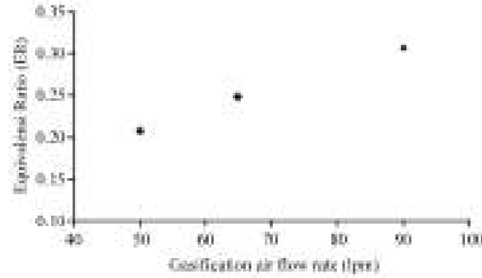

Fig. 2: Effect of gasification air flow rate against Equivalence ratio (ER)

Equivalence ratio process: The equivalency ratio is one parameter for control performance of gasification process where was the ratio of the total actual air flow rate for combustion to the total air flow rate for combustion 1 kg of fuel for stoichiometric condition. Figure 2 shows the test result by increasing of gasification air flow rate leads the increasing of equivalence ratio value. The range of equivalence ratio is between of 0.21-0.31.

Temperature inside reactor: Figure 3 shows time variation of temperature at equivalence ratio variation where increases equivalence ratio tend to increase temperature at combustion zone. Its because increase equivalence ratio will increase air gasification flow rate that will promotion to perfect combustion. At equivalence ratio 0.25 till 0.31 not very difference at this condition temperature increase faster to temperature 500°C where combustible gas appear. At equivalence ratio 0.21 temperature increase slower to temperature of 500°C it because air flow rate not sufficient to promotion faster combustion for released chemical energy and sensible heat. At each equivalence ratio combustible gas produce after temperature of 500°C where is suitable with reported by Seggiani, where the stable temperature condition about 30 till 40 min where was the same with

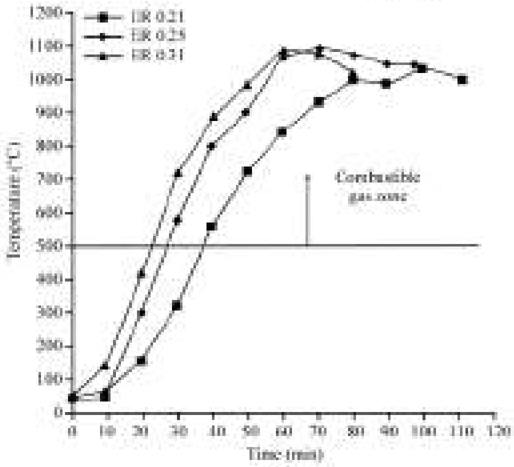

Fig. 3: Combustion temperature distribution against time at variation equivalency ratio

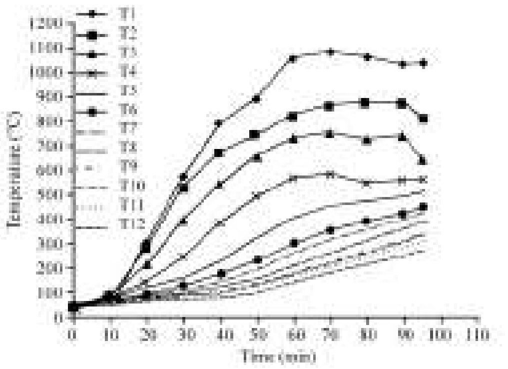

Fig. 4: Temperature distribution with time at each thermocouple position

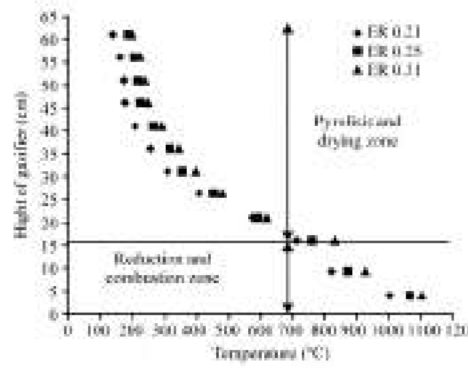

Fig. 5: Temperature variation against height of gasifier at different eequivalency ratio

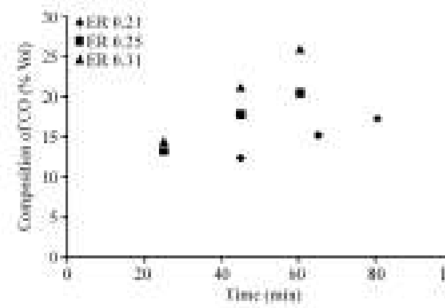

Fig. 6: The composition of CO againts time at variation of ER

result of Roa *et al.* (2004). The time for flare of combustible gas about 60 till 75 min. The combustion temperature reachs at combustion zone about of 1100°C.

Figure 4 shows time variation of temperature at each position of thermocouple where show significant increase and differences temperature at T1 till T4. The position of T1 till T4 are 20 cm from above reactor about 1/3 of height of reactor. The thermocouple T1 till T4 could reach a stable temperature about 40 min because at this time all moisture and volatile of batch fuel have released then char could promote more perfect combustion. At the thermocouple number 5-12, the temperature increases, this is because at this position the fuel move downward so absorption of heat by the fuel is also reduced in other hand temperature at combustion are still stable condition.

Figure 5 shows temperature variation with height of gasifier at different equivalence ratio. The increasing of equivalence ratio will increase temperature in combustion zone. At the height of reactor 0-15 cm from the bottom temperature are 700-1100°C occure as partial combustion and gasification zone. The drying and pyrolisis zone appear at 15 cm to the top reactor with the temperature range of 150-700°C. According to Seggiani, pyrolisis start at temperature of 200°C until 700°C, above temperature of 700°C gasification start. Several researches result pyrolisis process stop until temperature of 500°C (Ueki *et al.*, 2011; Jacjarnek *et al.*, 2011). Base on several researchers' argument could make conclusion pyrolisis process finish at T3 or the height of gasifier 15 cm in this gasifier design.

The combustible gas composition: Figure 6 shows the gas composition vary during gasification process. This variation occurs from the test begins until reaching the operation stable. The composition of CO tends to increase until reaching thestable operation that shown in Fig. 6.

The reaction of $C + CO_2 \rightarrow 2\,CO$ and $CH_4 + H_2O \rightarrow CO + 3\,H_2$ at reduction zone become more dominating at temperature of 850 till 900°C producing CO. The composition of CO is produced at the combustion zone, the reduction zone and the pyrolisis zone then whileat higher equivalence ratio would increase the composition of CO.

Figure 7 shows the composition of H_2 increases until temperature of about 900°C and then this tends to decrease at each equivalency ratio. Hydrogen was produced at pyrlisis and combustion zone. At pyrolisis zone where increasing time operation the fuel at zone pyrolisis would decrease that make the composition of H_2 decrease too. At reduction zone, the reaction with steam of $C + H_2O \rightarrow CO + H_2$ and $CH_4 + H_2O \rightarrow CO + 3H_2$ (Kumar *et al*., 2009) tend to increase with increasing of the temperature. According to the result of previous or other experiment H_2 will be produced at the temperature of 700-900°C (Turn, 1996; Evans *et al*., 1988; Pinto *et al*., 2003; Gomez-Barea *et al*., 2005). At this experiment temperature 700 till 900 at time about 40 till 60 min for ER 0.25 and 0.31 for ER 0.21 at time 50 till 80 min. The increasing of equivalence ratio tends increases temperature inside reactor that make the reaction at reduction zone would increase.

Figure 8 shows the composition of CH_4 will decrease with increase the time operation it is caused the composition of CH_4 is produced at pyrolisis and reduction zone. At pyrolisis zone where temperature pyrolisis start at 200°C so that have increased time operation, the fuel at zone pyrolisis will decrease then make the composition of CH_4 decrease too. At reduction zone the reaction of $C + 2\,H_2 \rightarrow CH_4$ will be decrease with increasing temperature. The increasing equivalent ratio tends to increase temperature inside reactor that make decrease reaction $C + 2\,H_2 \rightarrow CH_4$ (Kaupp and Gross, 1981).

LHV of producer gas: Figure 9 shows the lower heating value of producer gas will increase with increasing equivalence ration its caused the lower heating value main effected by the composition of CO that increased with increasing equivalent ratio. The lower heating value at stable operation for each equivalent ratio between range 3 till 4.2 MJ/m^3. The maximum of value of LHV at equivalence ratio 0.31.

Cold gas efficiency: Figure 10 shows the cold gas efficiency will increase with increasing equivalency ratio its caused the CGE more effected by LHV of the gas where increasing equivalency ratio will increase LHV of the producer gas. The cold gas efficiency achieves at 75% with equivalency ratio 0.31.

Tar content: Figure 11 shows the tar content will decrease with increasing equivalency ratio caused increasing

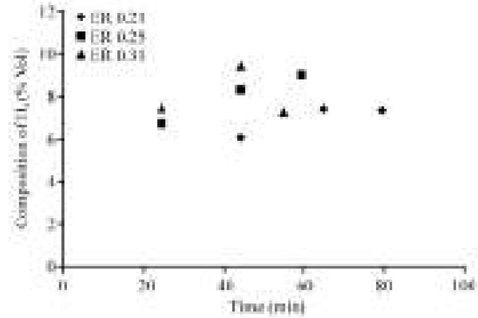

Fig. 7: The composition of H_2 againts time at variation of ER

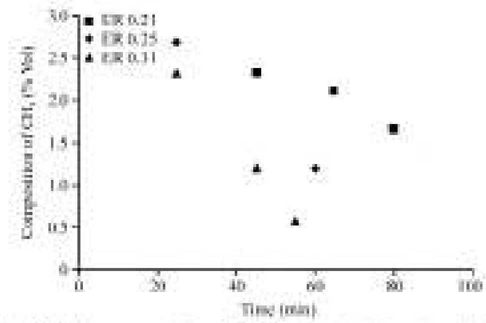

Fig. 8: The composition of CH_4 againts time at variation of ER

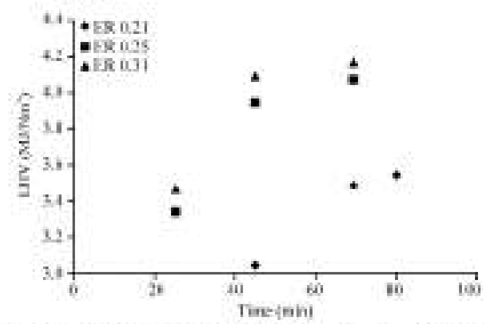

Fig. 9: The LHV of producer gas againts time at variation of ER

equivalency ratio would increase oxygen flow into pyrolysis zone make increasing partial combustion tar (pyrolysis product) to CO (Devi *et al*., 2003). At higher of equivalence ratio would lead the temperature inside reactor and then it would increase tar reaction with H_2O (steam reforming) and reaction tar with CO_2 (dry reforming) to produce CO (Morft *et al*., 2002). The result of this experimental has shown suitable with several studied gasification (Manya *et al*., 2006; Gomez-Barea *et al*., 2005; Hurley *et al*., 2012).

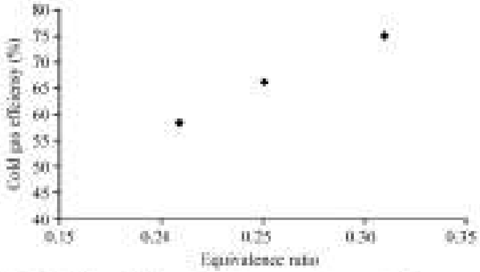

Fig. 10: The cold gas efficiency againts equivalency ratio at stable operation

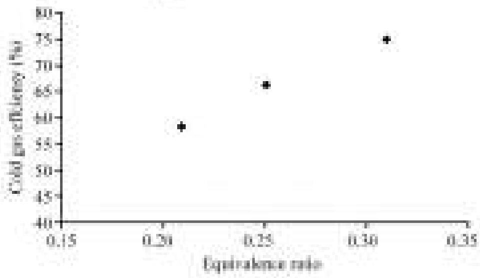

Fig. 11: Tar content againts equivalence ratio

CONCLUSION

Experimental study on a updraft gasifier system using rubber wood as fuel has been carried out at variation of equivalency ratio 0.21-0.31 for obtaining profile temperature distribution, zone gasification, gas composition, LVH, cold gas efficiency and tar content.

Increases equivalency ration tend to increase temperature distribution inside reactor. Gasification zone at height 0-15 cm of the reactor and pyrolysis zone at height 15 cm to the top reactor for each equivalency ratio. The composition of CO and H_2 tend to increase with increase equivalence ratio and time operation but for composition of CH_4 tend to decrease with increasing of equivalency ration and time of operation. The LHV of the gas tend to increase with increasing of equivalency ratio and time to stable operation where the LHV of the gas at stable operation at the range 3.6-4.2 MJ/Nm^3 with cold gas efficiency 55-75%. The tar content decrease with increasing equivalency ratio with minimum value 140 g/m^3.

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REFERENCES

Basu, P., 2010. Biomass Gasification and Pyrolysis: Practical Design and Theory. 1st Edn., Academic Press, USA., ISBN-13: 978-0123749888, pp: 170-171.

Brage, C. and K. Sjostrom, 2002. An outline of R&D work supporting the tar guideline. http://www.tarweb.net/pdf/final-td-report.pdf.

Devi, L., K.J. Ptasinski and F.J.J.G. Jansen, 2003. A review of the primary measures for tar elimination for tar elimination in biomass gasification processes. Biomass Bioenergy, 24: 125-140.

Evans, R.J., R.A. Knight, M. Onischak and S.P. Babu, 1988. Development of biomass gasification to produce subtitute fuels. Technical Report No. PNL-6514, Pacific Northwest Laboratory, Richland, WA., USA.

Gao, N., A. Li, C. Quan and F. Gao, 2008. Hydrogen-rich gas production from biomass steam gasification in an updraft fixed-bed gasifier combined with a porous ceramic reformer. Int. J. Hydrogen Energy, 33: 5430-5438.

Gomez-Barea, A., R. Arjonab and P. Ollero, 2005. Pilot-plant gasification of olive stone: A technical assessment. Energy Fuels, 19: 598-605.

Hurley, S., C. Xu, P. Preto, Y. Shao, H. Li and J.T. Wang, 2012. Guy, catalytic gasification of woody biomass in an air-blown fluidized bed reactor using canadian limonite iron ore as the bed material. Fuel, 91: 170-176.

Jain, A.K. and J.R. Gross, 2000. Determination of reactor scaling factors for throatless rice husk gasifier. Biomass Bioenergy, 18: 249-256.

Jacjaruek, K., S. Jarungthammachote, M. Kathrins, H. Wongsuwam and S. Homhual, 2011. Experimental study of wood downdraft gasification for an improved producer gas quality through an innovative two-stage air and premixed air/gas supply aproach. Bioresour. Technol., 102: 4834-4840.

Kaupp, A. and J.R. Gross, 1981. State of the art report for small scale (to 50 kW) gas producer-engine system. Technical Report No. PB-85-102002/XAD, Departement of Agricultural Engineering, University of California, Davis, CA., USA., pp: 28-44.

Khummongkol, D. and W. Arunlaksadamrong, 1990. Performance of an updraft mangrove-wood gasifier. Energy, 15: 781-784.

Kumar, A., D.D. Jones and M.A. Hanna, 2009. Thermochemical biomass gasification: A review of the current status of the technology. Energies, 2: 556-581.

Lucas, C., D. Szewczyk, W. Blasiak and R. Abeyweera, 2003. Gasification of biomass wastes in updraft fixed bed gasifier with high temperature air and steam. Proceeding of the Regional Conference on Energy Technology towards a Clean Environment, Feb. 12-14, 2003, Phuket, Thailand, pp: 1-6.

Mandl, C., I. Obernberger and Biederman, 2010. Modelling of an updraft fixed bed gasifier operated with softwood pellets. Fuel, 89: 3795-3806.

Manya, J.J., J.L Sanches, J. Abrego, A. Gonzalo and J. Aruajo, 2006. Influence of gas residen time and air ratio on the air gasification of dried sewage sludge in bubling in a bubling fluidized bed gasifier. Fuel., 85: 2027-2033.

Morft, P., P. Hasler and T. Nussbaumer, 2002. Mechanism and kinetics of homogeneous secondary reaction of tar from continuos pyrolisis of wood chips. Fuel, 81: 843-853.

Neefth, J.P.A., H.A.M. Knoef, U. Zielke, K. Sjostrom and P. Hassler *et al*., 2002. Guideline for sampling and analysis of tar and particles in biomass producer gases. Energy Project ERK6-CT1999-2002 (Tar Protocol).

Olgun, H., S. Ozdogon and G. Yinesor, 2011. Results with a bench scale downdraft biomass gasifier for agricultural and forestry residues. Biomass Bioenergy, 35: 572-580.

Pinto, F., C. Franco, R.N. Andre, C. Tavares, M. Diaz, I. Gulyurthu and I. Cabrita, 2003. Effect of experimental condition on co-gasification of coal, biomass and plastics wastes with air and steam micture in fluidized bed system. Fuel, 82: 1967-1976.

Ponzio, A., S. Kalizs and W. Blasiak, 2006. Effect of operation condition on tar and gas composition in high temperature air/steam gasification of plastic containing waste. Fuel Proc. Technol., 87: 223-233.

Pratik, N.S. and B.V. Babu, 2009. Experimental studies on producer gas generation from wood waste in a downdraft biomass gasifier. Bioresour. Technol., 100: 3127-3133.

Puig-Arnavat, M., 2010. Review and analysis of biomass gasification models. Renewable Sustainable Energy Rev., 14: 2841-2851.

Roa, M.S., S.P. Singh, M.S. Sodha, A.K. Dubey and M. Shyam, 2004. Stoichiometri, mass, energy and exergy balance analysis of countercurrent fixed bed gasification of post-consummer residues. Biomass Bioenergy, 27: 155-171.

Roch, C. and M. Kaltscmitt, 1998. State and prospect of biomass gasification. Proceedings of 10th European Conference and Technology Exhibition Biomass for Energy and Industry, June 8-11, 1998, Wurzburg, Germany, pp: 1798-1801.

Saravanakumar, A., T.M. Haridasan, T.B. Reed and R.K. Bai, 2007a. Experimental investigation and modelling study of long stick wood gasification in A top lift updraft fixed bed gasifier. Fuel, 86: 2846-2856.

Saravanakumar, A., T.M. Haridasan, T.B. Reed and R.K. Bai, 2007b. Experimental investigation of long stick wood gasification in a bottom lit updraft fixed bed gasifier. Fuel Proc. Technol., 88: 617-622.

Sharma, A.K., 2009. Experimnetal study on 75kW$_{t}$ downdraft biomass gasifier system. Renewable Energy, 34: 1726-1733.

Turn, S.R., 1996. An introduction to combustion concept and aplication. International Edn., McGraw-Hill, New York.

Ueki, Y., T. Torigoe, O. Hirofumi, Y. Ryo, J.H. Kihedu and I. Naruse, 2011. Gasification characteristic of woody biomass in the packed bed reactor. Proc. Comb. Inst., 33: 1795-1800.

Zainal, Z.A., A. Rifau, G.A. Quadir and K.N. Seetharamu, 2002. Experimental investigation of a downdraft biomass gasifier. Biomass Bioenergy, 23: 283-289.

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