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EFFECT OF GASIFIYNG AGENT (AIR+STEAM) INJECTION TOWARDS SYNGAS QUALITY FROM RICE HUSK GASIFICATION

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ABSTRACT

Biomass gasification is more benefit compared to direct combustion because of more flexibility gas product that can be directed use as combusted gas in gas engine power generation or chemical feedstocks as well as synthetic fuel belongs to added market value. Since 2007, PT National Champignon (PT Natcham) in Wonosobo – Central Java have been operating 1 (one) unit of fixed–bed updraft gasifier by rice–husk fuel feeding using air as gasification agent for it's mushroom plant electricity needs through gas engine 400 kW. Fluctuation of gasifictaion temperature in each of gasifier zones is affected by injection pressures of air+steam, as well as opening valves of air and steam. The optimum steam injection can only be carried–out at opening valve of steam 50% and air of 7/19 (volumetric ratio of steam/air = 0.6–0.7) with bottom temperatur of gasifier, T_{bottom} = 650^oC at pressure condition of 4,5 bar. Syngas with H_2/CO ratio of 1,26– 1,71 have sufficient met the requirements of syngas quality for synthesis process of Fischer–Tropsch to be processed futhermore for synthetic fuel producing.

Keywords : rice husk, air+steam gasifying agent, synthetic gas

1. INTRODUCTION

Since 2007, PT. Dieng National Jaya (before) or PT. National Champignon (now) in Wonosobo - Central Java has operated a fixed-bed gasifier unit with feed rice husk as fuel for electricity generation purposes mushroom factory itself through power generation gas engines 400 kW.

In the fixed-bed gasifier, rice husk is fed to be fluidized until temperature around 800^oC to produce synthetic gas (syngas). Syngas coming out of the gasifier has a temperature of 750^oC is passed through a cyclone separator to clean the coarse particles, then cooled through a series of ventury scrubbers and cooling tower. Clean gas that has been cool pumped through a high voltage electrostatic precipitator to remove dust particles and tar is left before it is used in a gas engine to generate electricity.

Initially, the burning of rice husk in the form of tar greatly feared, but have now been fully resolved by adding tar processing system that integrates with existing environmental equipment or separate pyrolysis and gasification zones like a two-stage gasifier [3].

Biomass gasification is more profitable than direct combustion, because the gas product is more flexible that can be directed into the fuel gas for gas engine power plant or chemical industry feedstock and synthetic liquid fuel that have a higher sale value. Biomass utilization efficiently developed to meet the energy needs has the dual advantage of reducing dependence on commercial energy and environmental protection [3].

Syngas development from rice husk gasification is expected to be further processed into synthetic liquid fuels to support the Presidential Regulation No. 5 of 2006 on the national energy policy and Presidential Instruction 1 of 2006 on the energy mix (energy-mix) in supplying and biofuels utilization.

2. LITERATUR REVIEW

Biomass containing cellulose, hemi-cellulose, lignin ($C_6H_{10}O_5$), oxygen excess and low calorific value ranging from 12-16 MJ / kg [7] has a high potential in contributing to the energy needs of modern society. Just selected biomass that can be converted into biogas, ethanol, biodiesel through chemical and biochemical processes, otherwise most biomass materials can experienced thermochemical conversion, making this process more interesting than others.

Among thermochemical conversion technologies, biomass gasification has attracted the attention of that offer higher efficiencies than combustion. In the complete combustion of biomass in theory stoichiometri amount of air consumption = 6-6.5 kg of air / kg of biomass with end product CO_2 and H_2O. In the gasification, biomass experienced partial pyrolysis sub-stoichiometri condition with a limited air 1.5-1.8 kg of air / kg of biomass [6].

Interest in biomass gasification reoccur after the energy crisis of the 1970s. Gasification technology began to be perceived as a relatively inexpensive alternative for small-scale industrial and utility power plants, particularly for developing countries that suffer because of high oil prices while having sufficient availability of biomass resources [9].

Gasification is a partial oxidation process between carbon and gasifying agent (air/O_2/*steam* or mixtures) at temperature around (500–1400ºC) which produce producer gas (synthesis gas or syngas) CO, H_2, CO_2, CH_4, high hydrocarbon i.e: ethane, ethene, H_2O steam, N_2 (if the air used for oxidation agent) and various impurities (small particles of charcoal, ash, tar, oil). Gasification relies on chemical processes at elevated temperatures (500–1400ºC) distinguishing of biological processes such as anaerobic digestion that produce biogas [6].

Figure 1 shows the differences in design and characteristics of the reaction zone fixed-bed gasifier, in which the fuel particles is not driven by the flow of gas to the fuel arranged in a fixed bed gasifier. Most of the fuel feed is placed on a pedestal fluidized–bed while the rest of the combustion in the form of charcoal and ash removed from the bottom of the pedestal fuidized–bed. Biomass fuel moves from the top to the bottom of the fuel bed pedestal so that the residence time of fuel in the gasifier is relatively long..

Special design consists of a gasifier feeding fuel from the bottom of the fuel bed pedestal. Depending on the direction of the product gas flow to the direction of transport fuels in the fixed-bed gasifier classified into co-current (unidirectional), counter-current (and cross-flow. The gasification process stages occurs in four (4) zones, namely drying (>150°C), pirolysis (150^{o}C<T<700°C), oxydation (700^{o}C<T<1500°C), and reduction (800^{o}C<T<1000°C).

Pyrolysis or devolatilization is a series of physical and chemical processes occurring slowly at temperatures <350°C and rapidly at temperatures> 700°C. Composition of the gas product composed is a function of temperature and pressure during pyrolysis takes place.

Pyrolysis process starts at temperatures around 230°C, when the component thermally unstable, such as lignin broke and evaporate along with other components. Vaporized liquid product containing tar and PAHs (polyaromatic hydrocarbons). Pyrolysis products are generally composed of light gases (H_2, CO, CO_2, H_2O, CH_4), tar, and char.

Oxidation is the most important reactions occurring in the gasifier which provide all the energy needed to heat the endothermic reaction. Oxygen is supplied to the gasifier reacts with combustible material. The reaction products are CO_2 and H_2O are sequentially reduced when in contact with the charcoal produced in pyrolysis.

$$C + O_2 \rightarrow CO_2 + 393{,}77\ \frac{kJ}{mol\ C}$$

Another reaction that takes place is the oxidation of hydrogen contained in the carbon material formed steam

$$H_2 + {}^{1}\!/_{2}\, O_2 \rightarrow H_2O + 742\ \frac{kJ}{mol\ H_2}$$

- Reduction or gasification reaction that includes a series endothermic supported by the heat produced from the combustion reaction. The resulting product is a fuel gas, such as H_2, CO, and CH_4. There are four (4) common reactions associated gasification process, namely:

- *Water–gas reaction* is a partial oxidation reaction of carbon by steam which can be derived from the pyrolysis of solid fuels itself and of the water vapor is mixed with air and water vapor evaporation results.

$$C + H_2O \rightarrow H_2 + CO - 131{,}38\ \frac{kJ}{mol\ C}$$

- *Boudouard reaction* is the reaction between CO_2 that occur in the gasifier with CO to produce char.

$$C + CO_2 \rightarrow 2\ CO - 172{,}58\ \frac{kJ}{mol\ C}$$

- *Shift conversion* is the CO_2 reduction reaction by steam to produce H2. This reaction is known as the water-gas shift which results in an increase in the ratio of H_2/CO_2 gas producer to manufacture syngas.

$$CO + H_2O \rightarrow CO_2 + H_2 - 41{,}98\ \frac{kJ}{mol}$$

- *Methanation a gas-forming reaction* CH_4.

$$C + 2\ H_2 \rightarrow CH_4 + 74{,}90\ \frac{kJ}{mol\ C}$$

Fixed bed gasification system consists of a gasifier is equipped with cooling and gas cleaning systems. Fixed-bed gasifier has a pedestal bed of solid fuel particles, gasifying agent and gas moves slowly up and down so that the gasification reaction occurs with high carbon conversion, residence time of fuel relative, low gas velocity and low recovery ash [2].

The simple gasifier typically consist cylindrical chamber made of firebricks with foundation steel and concrete for fuel gasification and feeding agent to the unit, the unit discharge ash and gas output. In the *fixed–bed gasifier* experiencing difficulties in tar waste problem, but now the conversion progress in thermal and catalytic tar provide a reliable option. Cooling and gas cleaning system consists of filtration through the cyclone, the absorption of dry / wet (*dry/wet scrubbers*) [2].

There are many types of fixed-bed gasifier with a variation of reactor design and gasifyig agent can be classified according to how the gasifyig agent entrance gasifier, namely: updraft, downdraft, and crossdraft gasifier. Gasifyig agents can be air, steam, O_2 or mixtures and producer gas can be used as a heating or power generation applications. Diversity of producer gas composition and contamination level depends on the selection of biomass, gasifier type and operating conditions [1].

Table 1. Syngas composition by gasifying agent used

Gas Component %vol. dry	Gasifying Agents		
	Air	Air (80% O_2)	*Steam*
CO	10 – 20	40 – 50	25 – 47
H_2	9 – 20	9 – 17	35 – 50
CH_4	1 – 8	<1	14 – 25
CO_2	10 – 20	19 – 25	9 – 15
N_2	40 – 55	15 – 30	2 – 3
Calorific Value (MJ/Nm^3, dry)	4 – 6,5	7 – 9	12 – 17

Source: Bioenergiesysteme GmbH

Updraft gasifier is a type of the oldest and simplest fixed-bed gasifier that can handle biomass fuels with high ash content (>15%) and high water content (>50%), but less sensitive to the diversity of size and quality of the biomass. In the counter-current updraft gasifier, biomass entering from the top of reaction chamber and the gasifying agents (air, O_2 or mixtures thereof) entered from the bottom grate. Fuel flows slowly down through the 4 stages of zones, namely: drying, pyrolysis, gasification and combustion, and ash removed from the bottom.

Updraft gasifier has a sensible heat efficiency of high gas producer that can be obtained through direct heat exchange with the pyrolysed fuel feeding experiencing dry before entering the gasification zone. Producer gas out at low temperatures (80~300ºC) and tar rich in oil content (10~20%) considering the products from the pyrolysis and drying zone issued directly without experiencing decomposition. Dust content of the producer gas is low because the gas velocity is slow and the impact on the fuel feed filtration drying and pyrolysis zone. [2], [9].

Downdraft fixed-bed gasifier designed stainless steel coated cylinder, where combustion reactions take place in the smaller cylinder is made of high temperature steel is placed inside the outer cylinder. Fuel breaks grate attached to the bottom of the reaction chamber combustion periodically shaken by two rods to let the ash fall on the base plate main room.

Some fuel feeding through the base plate holes for entering air and K type thermocouple (Omega) into the combustion chamber to monitor the reaction temperature. Two cartridge heaters inserted in the combustion chamber wall to initiate biomass combustion using air as agasifying agent supplied from a compressor that has a pressure regulator and rotameter.

The fuel is fed from the top through the director funnel into the combustion chamber. During the combustion process, combustion chamber is closed in order to syngas move downward through the holes of the fireplace that is directed to the channel between the combustion chamber and the outer cylinder. Syngas which leads out to a Bunsen burner that burns in a hood [5].

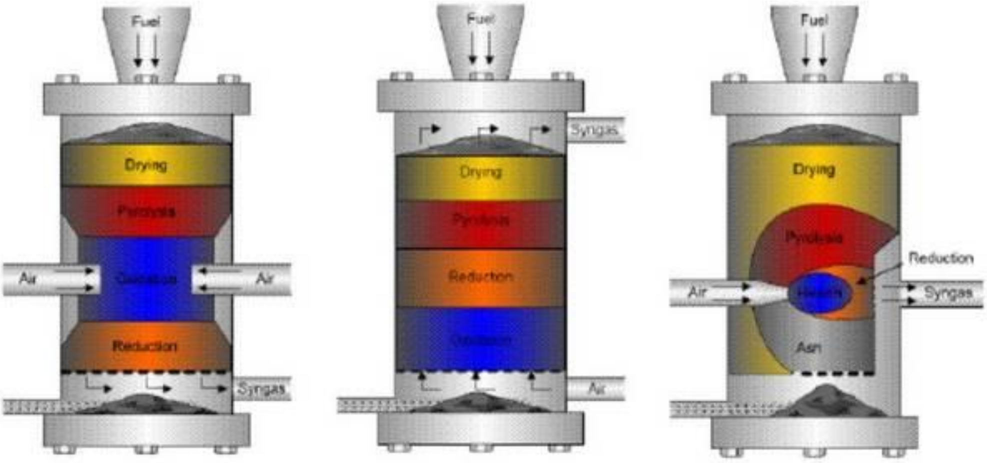

Figure 1. Differences in design and characteristics of the reaction zone fixed-bed gasifier [8]

Figure 2. Fixed–bed updraft gasifier (Rice husk) PT. Natcham Wonosobo – Central Java

In the crossdraft gasifier, the fuel moves downward while air is introduced on one side and the producer gas (800-900^{o}C) out of the opposite side, while the ash removed from the bottom of the gasifier. Overall energy efficiency is low and tar content is high in the producer gas are mostly used for boiler closed circuit. Crossdraft type gasifier has limitations tar chap, so it is only suitable for low tar fuel, the implementation does not lead to industrial scale [4], [9].

Application of biomass gasification mainly carried out in the fixed-bed and fluidized-bed gasifier. Fixed-bed gasifier is the most practical option for producing low calorie gas and suitable for use in small-scale power plants (<10 MWth) or heating applications, while the fluidized-bed gasifier is very effective to be applied on a larger scale power plants (> 15 MWe) [2].

The potential use of the syngas is more efficient than direct combustion, as it can burn at higher temperatures, so that the thermodynamic efficiency defined by Carnots higher or even not feasible applicability. Syngas can be burned directly in internal combustion engines to produce methanol and H2, or converted via the Fischer-Tropsch Synthesis becoming synthetic fuel.

3. RESEARCH

Tests carried out at PT. National Champignon Wonosobo–Central Java by utilizing the updraft fixed-bed rice husk gasifier plant as shown in Figure 2.

3.1. Purpose

Determine the effect of air+steam injection on the syngas quality of rice husk gasification results as feeding Fischer-Tropsch synthesis process to produce synthetic liquid fuels.

3.2. Materials

- Rice husk as raw material is fed from the silo through a screw conveyor (410 kg / hour = 250 rpm) into the gasifier, with specifications as shown in Table 1.
- Air (ρ = 1,16 kg/m^3, μ = 1,84 10^{-5} N.sec/m^2, g = 9,807 m/sec^2) as gasifying agent is fed through air blower into gasifier.

Table 1. Specification of rice husk

Compound		Composition
Cellulose		: 35%w
Hemicellulose		: 25%w
Lignin		: 20%w
Crude Protein		: 3%w
Ash (Silica)		: 17%w
Proximate Analysis		**Composition**
Volatile Matter	VM	: 60,30%w
Fixed Carbon	FC	: 17,00%w
Ash		: 22,70%w
Ultimate Analysis		**Composition**
Carbon	C	: 29,33%w
Hydrogen	H	: 3,90%w
Oxygen	O	: 29,17%w
Nitrogen	N	: 0,24%w
Sulfur	S	: 0,16%w
Water	H_2O	: 22,70%w
Ash		: 14,50%w
Physical Properties		
Diameter	∅	: 0,5 mm
Density	ρ	: 300 kg/m^3
Spericity	φ	: 0,65
Porosity		: 0,5

Source: PT. Natcham

- Superheated steam (P= 1 atm, T= 200°C, ρ= 2,5 kg/m^3) as gasifying agent is fed from steam boiler
- Standard gas wiy\th composition (83%N_2, 5,09%H_2, 5,18%CO, 1,05%CH_4, 5,68%CO_2), is used for *Gas Chromatography* (GC) calibration.

3.3. Equipments

3.3.1. Fixed–bed updraft gasifier plant (Figure 2) consisting of:

- Feeding system (Table 2), consisting of:
  - Screw conveyor (410 kg/hour = 250 rpm), rice husk carrier from warehouse to silo
  - Silo, rice husk storage.
  - Screw feeder, rice husk feeder from silo into gasifier.

- Gasification system (Table 3), consis of:
  - Fixed–bed gasifier made in Peako China that operate in counter-current moving-mode, in which the flow of gas products and feed materials in the opposite direction, while the gasifying agent (air / steam / oxygen) in the opposite direction with feed material.
  - Air blower (1.440 m^3/hour = 0,4 m^3/sec), air feeder into gasifier.
  - Cyclone (150 rpm), gas products separator with solids bandwagon.

- Product gas cleaning system (Table 4), consist of:
  - Water scrubber, cleaning gas products using a water-spray gas.
  - Electrostatic precipitator, the dust collector and tar entrained gas product using electrostatic force induced charge.
  - Root blower (400 rpm), driving gas products to storage (gas holder).
  - Gas holder, penampung produk gas.

- Ash removal system (Table 5), terdiri dari:
  - Screw conveyor (200 rpm), ash carrier.
  - Ash/char storage with dimension 5,25mx4,70mx4,00m.

3.3.2. Steam boiler

Steam boiler 1 ton saturated steam/hour (P= 4–6 bar, T= 143,6–158,8°C, ρ= 2.162–3.168 kg/m^3, V= 374,8 m^3/hour) through steam header (Figure 3) into gasifier.

Figure 3. *Steam superheater*

3.3.3. Gas engine power generation 400 kW

Pc(P=5 bar, T= 170–200°C, ρ=2,5 kg/cm^3)ind of reciprocating gas engine (Figure 4) is more compact and simple, so combustible syngas can be used directly as a fuel for electricity generating 400 kW.

Figure 4. Gas engine power generation 400 kW

Gas Chromatography (GC) is used to analyze samples taken syngas in gas sampling valve after the gas holder before entering the gas engine uses aluminum-foil bags with 15-minute intervals during each sampling.

Figure 5. *Gas Chromatography* (GC)

3.4. Metodology

3.4.1. Rice husk gasifier system operation using air+steam as gasifying agent

- Operating condition:
  - Rice husk feeder: 410 kg/hour (250 rpm)
  - Ash screw conveyor: 200 rpm
  - Cyclone lock: 150 rpm
  - Root blower: 400 rpm
- Variable valve opening operation:
  - Steam (25%, 50%, 75%)
  - Air Blower (7/19, 6/19, 5/19, 4/19)

3.4.2. Analysis and evaluation against composition and syngas characteristic.

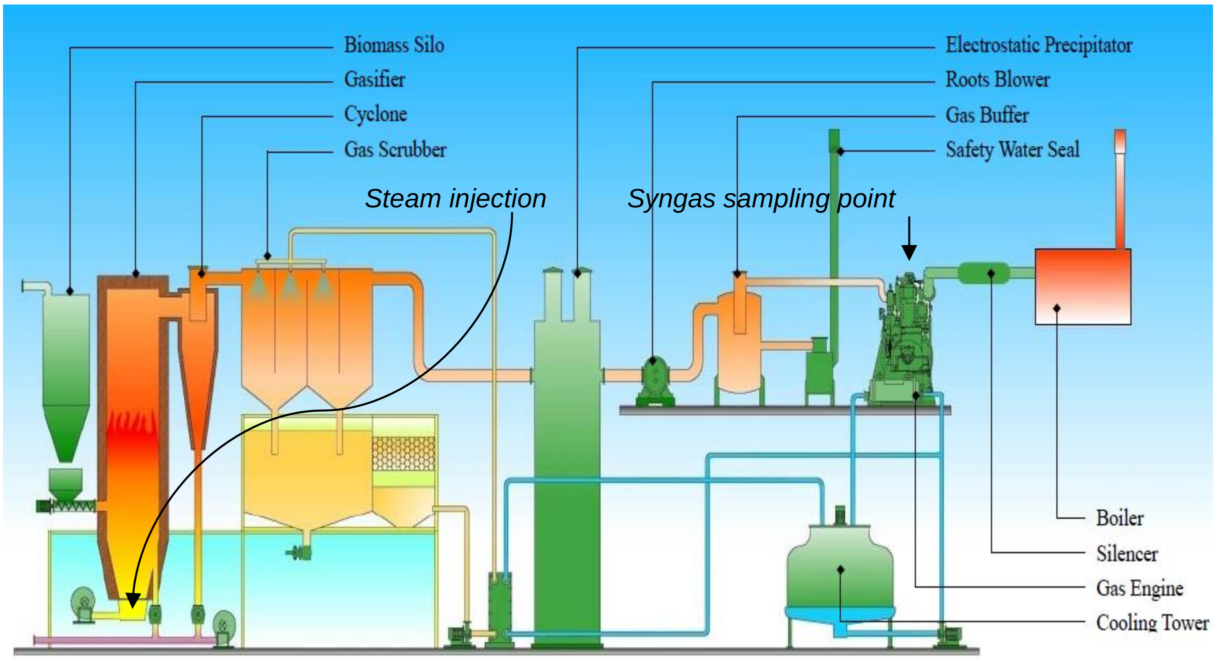

Figure 6. Flow diagram process of rice husk gasificatio PT Natcham

Table 6. Condition and variablel Operation fixed–bed updraft gasifier

Opening Valve		Steam Pressure (P_{steam}, bar)	Gasifier Temperatue, °C				
Steam	Air		T_{bottom}	T_{middle}	$T_{top\ 1}$	$T_{top\ 2}$	$T_{top\ 3}$
Air		6	785	770	737	642	517
75%	7/19	4	783	762	756	657	568
		5	794	784	746	611	484
50%	7/19	4,5	648	634	614	527	438
		4,5	656	636	614	523	436
		4,5	677	650	611	514	430
	6/19	4	645	625	615	538	444
		5	647	633	617	533	441
		6	645	629	617	540	446
	5/19	5,5	642	625	619	544	455
		4	636	623	620	552	462
	4/19	4,5	628	610	610	553	467
		5	617	605	603	551	471
25%	4/19	5	842	809	624	509	429
	5/19	6	772	757	648	542	450
	6/19	4	755	748	639	534	445
	7/19	4,5	733	727	631	530	441
Air		6	771	767	730	642	527

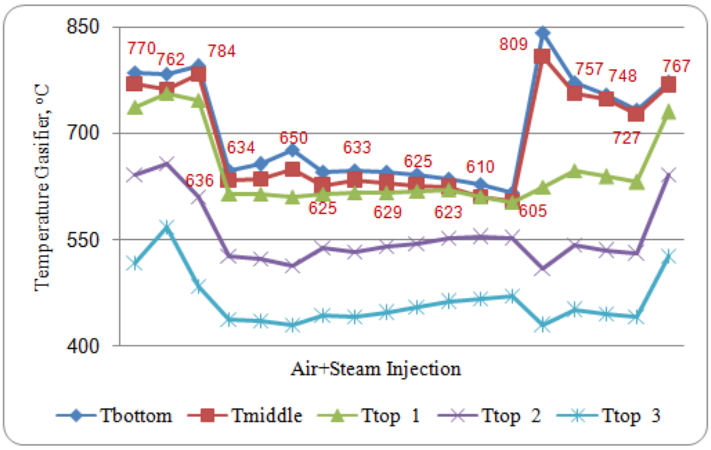

Figure 7. Correlation between air+steam injection and temperature gasifier

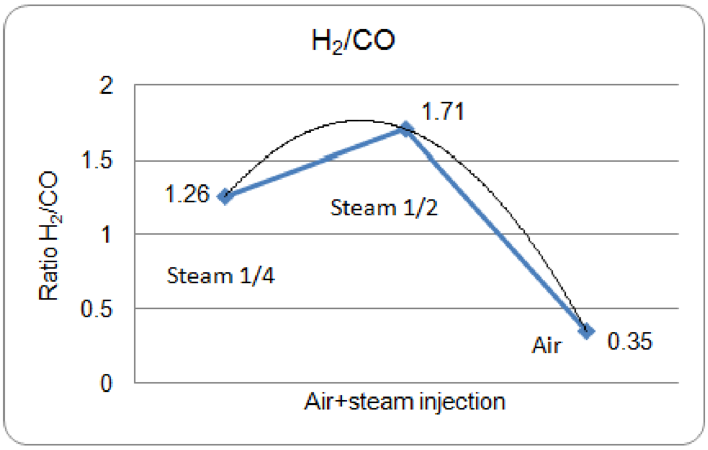

Figure 8. Correlation between air+*steam injection* and rasto H_2/CO

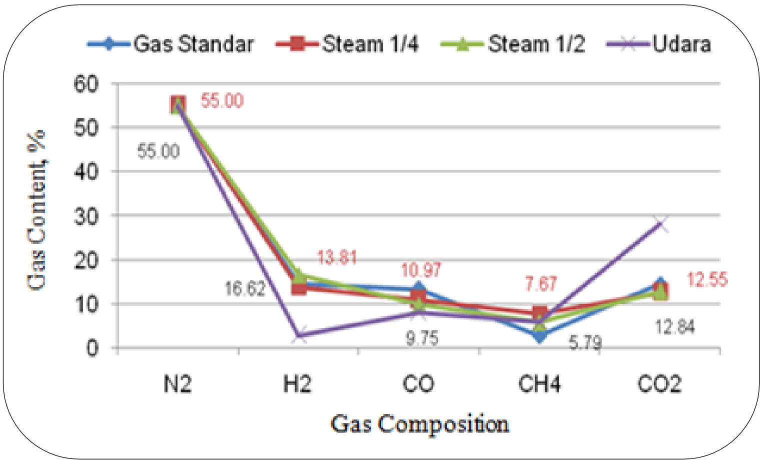

Figure 9. *Syngas quality*

4. RESULT AND DISCUSSION

Operation of rice husk gasifier systems using air+steam as gasifying agent shown in Figure 6, with operating conditions: feed rice husk: 410 kg / hour (250 rpm), ash conveyor screw rotation: 200 rpm, lock cyclone rotation: 150 rpm, round root blower: 400 rpm, and steam injection valve openings (25%, 50%, 75%), injection valve opening air blower (7/19, 6/19, 5/19, 4/19).

Table 6 shows the gasifier operating temperature conditions (T_{bottom}, T_{middle}, $T_{top\ 1}$, $T_{top\ 2}$, $T_{top\ 3}$) at the variation of steam injection valve opening (25%, 50%, 75%), blower air injection valve opening (7/19, 6/19, 5/19, 4/19) and steam pressure (4–6 bar).

Table 7 shows the standard gas composition (according to the label, GC, and calculations) that used for instrument calibration Gas Chromatography (GC).

4.1. Results

Table 7. Standard gas composition

Compound	Standard Gas , %		
	Label	GC	Calculation
N_2	83,00	82,5347	55,0000
H_2	5,09	5,6689	14,6061
CO	5,18	5,1433	13,2519
CH_4	1,05	1,0379	2,6742
CO_2	5,68	5,6152	14,4678
Total	100	100	100

Table 8 shows the syngas composition of rice husk gasification results using air without steam as gasifying agent.

Table 8. Syngas composition
Gasifying agent: Air without Steam

Component	Syngas content, %	
	GC	Calculation
N_2	79,3842	55,0000
H_2	1,2939	2,8243
CO	3,7162	8,1117
CH_4	2,6890	5,8695
CO_2	12,9168	28,1947
Total	100	100
	Ratio H_2/CO	0,35

Table 9 and Table 10 respectively show the syngas composition of rice husk gasification results using air+steam at the steam valve opening 25%, and 50%.

Table 9. Syngas composition
Gasifying agent: Air+Steam
Steam valve opening: 25%

Component	Syngas content, %	
	GC	Calculation
N_2	81,2289	55,0000
H_2	5,7624	13,8142
CO	4,5745	10,9665

CH_4	3,1977	7,6659
CO_2	5,2365	12,5535
Total	100	100
	Ratio H_2/CO	1,26

Table 10. Syngas composition
Gasifying agent: Air+Steam
Steam valve opening: 50%

Component	Syngas content, %	
	GC	Calculation
N_2	74,0395	55,0000
H_2	9,5897	16,6228
CO	5,6255	9,7513
CH_4	3,3397	5,7890
CO_2	7,4056	12,8369
Total	100	100
	Ratio H_2/CO	1,71

Figure 7 shows the correlation between air+steam injection and temperature gasifier, while Figure 8 shows the correlation between air+steam injection and H_2/CO ratio, while Figure 9 shows the syngas quality.

4.2. Discussions

The syngas quality of rice husk gasification results using fixed-bed updraft gasifier is strongly influenced by air+steam injection.

4.2.1. Temperature of Gasifier

At first, the gasifier operating conditions as shown in Table 6 and Figure 7 at a pressure of 6 bar and temperature gasifier (Tmiddle) 767^{o}C, then steam is injected at a pressure of 4 bar with 75% steam valve openings and air injection with 7/19 of air valve opening, temperature gasifier (T_{middle}) increased to 784^{o}C

When air+steam injection (50% steam valve opening and 7/19 air valve opening), T_{middle} gasifier gradually decreased up to 650^{o}C at a pressure of 4.5 bar. Even tried to change the air valve opening 6/19, 5/19, 4/19 instead (T_{middle}) gasifier drastically dropping to 605^{o}C at a pressure of 5 bar. Furthermore, the steam valve opening set 25% while the air valve opening remains 4/19, (T_{middle}) gasifier increased back up to 809^{o}C. But after opening the air valve successively changed from (5/19, 6 bar), (6/19, 4 bars), and (7/19, 4.5 bar) with steam valve openings remain 25%, (T_{middle}) gasifier has decreased up to 727^{o}C. Finally, the gasifier operation carried out by air injection without steam at a pressure of 6 bar, so that the gasifier temperature (T_{middle}) back up to 767^{o}C.

The phenomena tendency of air+steam injection influence against the gasifier temperature was also experienced by the entire zone gasifier temperature (T_{bottom}, $T_{top\ 1}$, $T_{top\ 2}$, $T_{top\ 3}$).

4.2.2. Ratio H_2/CO

Table 8, Table 9, Table 10 and Figure 8 shows that by injection of steam mixed by air as gasifying agent will increase the H_2/CO ratio of 0.35 (air), 1.26 (air + 25% steam valve opening), and 1,71 (air + 50% steam valve opening), thus improving the quality of the resulting syngas. Thus, the addition of steam mixed by air as gasifying agent under certain conditions predicted H_2/CO ratio increases.

4.2.3. Quality of Syngas

Table 9, Table 10, and Figure 9 shows that the composition and content of syngas by the ratio H_2/CO = 1.26 to 1.71 has been sufficient to meet the requirements of quality feed for Fischer-Tropsch synthesis process (H_2/CO ratio

> 1) to be processed further synthetic liquid fuels.

However, it has not obtained rice husk gasification operating conditions that optimum in the fixed-bed updraft gasifier to produce syngas by a high yield (> 30%), considering the operating temperature that still allows> 650°C.

5. CONCLUSSION AND RECOMMENDATION

Based on the results and the discussion above mentioned, it can be some of the following:

5.1. Conclusion

- Fluctuations in the gasification temperature of each gasifier zone is affected by variations in pressure air+steam injection, as well as variations in steam and air valve opening.
- Steam injection that can only be done at the maximum steam valve opening of 50% and air valve opening of 7/19 (volumetric ratio of steam / air = 0.6-0.7) by temperature gasifier performance T_{bottom} = 650°C at a pressure of 4.5 bar.
- Steam injection in the steam valve opening of 75% and air valve opening of 7/19 occured gasifier temperature decrease drastically..
- Injection of steam mixed by air as gasifying agent will increases H_2/CO ratio, thus increasing the quality syngas.
- The quality syngas by the ratio $H_2/CO = 1.26$ to 1.71 has been sufficient to meet the feed requirements of the Fischer-Tropsch synthesis process (H_2/CO ratio > 1) for further processed into synthetic liquid fuels.

5.2. Recommendation

- Need additional steam and air flowmeter, to be observed each flow rate to determine the volumetric ratio steam / air.
- Given the temperature operation of rice husk gasification in a fixed-bed updraft gasifier that still allows > 650°C, it still needs further testing to produce syngas that optimum by high yield (> 30%).

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Table 2. Technical specification of feeding system

Screw Conveyor		Specification
Diameter axis	inchi	1,5
Diameter *casing*	inchi	6
Length	m	18
Screw spacing (pitch)	cm	14
Rotational speed	rpm	600 – 800
Motor power	kW	4
Silo		Specification
Dimention	cm	207 x 200 x 375
Screw Feeder		Specification
Feeding rate	kg/jam	460 – 480
Diameter axis	inchi	1,5
Diameter *casing*	inchi	10
Length	m	18
Screw spacing (pitch)	cm	22
Rotational speed	rpm	250 – 300
Motor power	kW	2,2

Source: *Peako* – China

Table 3. Technical specification of gasification system

Air Blower		Specification
Pressure	MPa	4,704
Pushing rate	m^3/detik	0,4
Rotational speed	rpm	2900
Motor power	kW	4
Motor rotation	rpm	2890
Electrical voltage	Volt	380
Electric current	Ampere	8,2
Gasifier		Specification
Type		*Up–draft fixed–bed*
Made in		*Peako China*
Basic temperature measurement	cm	80, 160, 340, 520, 700
Basic pressure measurement position	cm	250
Cyclone		Specification
Diameter main space	cm	70
Heigth	cm	340
Inlet	cm	35 x 15
Diameter *outlet gas*	cm	36
Diameter *outlet* solids	inchi	6
Rotational *cyclone lock*	rpm	150

Source: *Peako* – China

Table 4. Technical specification of syngas cleaning syatem

Water Scrubber		Specification
Diameter axis	inchi	1,5
Diameter *casing*	inchi	6
Length	m	18
Screw spacing	cm	14
Rotational speed	rpm	600 – 800
Motor power	kW	4
Electrostatic Precipitator		Specification
Height	cm	780
Diameter	cm	175
Temperature *inlet*	^{o}C	28
Temperature *outlet*	^{o}C	34
Electrical voltage	kV	32 – 40
O_2 *setting*	%	1,5
O_2 *measured*	%	0,6 – 0,9
Root Blower		Specification
Gas flow rate	m^3/menit	32,6
Pressure	KPa	9,8
Rotational speed	rpm	1450
Motor power	kW	11
Gas Holder		Specification
Pressure	mmH_2O	300
Size	cm	230 x 190

Source: *Peako* – China

Table 5. Technical specification of ash removal

Screw Conveyor		Specification
Diameter axis	inchi	1,5
Diameter *casing*	inchi	6
Length	m	18
Screw spacing	cm	14
Rotational speed	rpm	200
Motor power	kW	4
Ash/CharPit		Specification
Size	m	5,25 x 4,7 x

Source: *Peako* – China