# RICE HUSK GASIFIER IN UITM PENANG AS ENERGY: A DESIGN REVIEW

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## ABSTRACT

*To reduce dependency on fossil fuel, reduce pollution and move into green technology, the rice husk gasification has been developed as the process that converts organic rice husk into a producer of gas. However, drawbacks such as grate blocking, bridging and suitability of feedstock are found in the gasifiers. Design of the gasifiers is an important objective and improvements on the design have been done to enhance the performance of the gasifiers. This paper aims to review gasifiers focused on design improvements. Many works from previous researchers have been studied. The result shows the new design of the gasifiers is an important parameter in gasification.*



**Keywords**: Downdraft gasifier, rice husk, gasification

## INTRODUCTION

Biomass energy is derived from five distinct energy sources which are garbage (Solid waste), wood and agricultural products, waste, landfill gases, and alcohol fuels (Pradhan, Ali, & Dash, 2013). Rice husk is one of the biomass sources where the materials are readily available in large quantities but easily collected. The choice of the energy is due to the demand of energy in industries and households which are extremely high. Renewable energy is the right alternative energy source that can be substituted for fossil fuels.

Current environmental problems are caused by numerous factors including global warming due to emissions of greenhouse gases (GHGs) which are generated mainly from the combustion of fossil fuels such as diesel, gasoline or coal (Quispe, Navia, &Kahhat, 2017). In order to overcome future problems, there are policies that the government had proposed to increase the share of renewable energy resources. In these sectors, all the research studies are aimed to obtain energy from various biomass including agricultural solid residues, such as coffee husks, rice husks, sugar cane bagasse and wheat straw. Among the rest, rice husk is the least used in developing countries. Biomass is a promising and renewable energy source that is estimated to contribute 10% to 14% of the world's energy supply (Ma, Zhang, Zhang, Qu, Zhou, & Qin, 2012).

Rice husk (or rice hull) is the hard protecting cover of grain of rice which is indigestible to humans. Its main function is to protect the seed during growing season. It produces consistent amounts annually which makes it possible to secure a raw material supply (Yoon, Son, Kim, & Lee, 2012). Based on the statistic, the amount of rice produced by the world annually is more than 120 million tonnes. This shows that Malaysia has the potential to be the new producer of bio-energy. Following the report from USDA Foreign Agricultural Service (2017), the forecast of rice production in Malaysia is at 1.8 million tonnes in 2016/17 and increasing to 0.02 million tonnes in 2017/18. It is a major by-product of the rice-milling industries and is abundantly available. South and Southeast Asia account for over 90% of the world's rice production (Lin, Wang, Lin, &Juch, 1998). However, rice husks have been considered a waste, causing disposal problems. Asia itself produces the vast majority of global rice at around 770 million tonnes annually. 20% of the rice weight can be attributed to the husk or hull which is not consumed and often disposed of. This equates to 150 million tonnes of biomass fuel annually.

Gasification is a thermo-chemical process of converting carbonaceous materials into gaseous products using a gasifier with a gasifying medium such as air, oxygen and steam either alone or in mixture (Ma, Ye, Zhang, & Zhao, 2015). The producer gas as the output could be used as a fuel in engines for power generation; thus, it is a promising technology to provide electricity in remote districts by using local, renewable fuels (Ma, Zhang, Zhang, Qu, Zhou, & Qin, 2012). Producer gas is a product of gasification, exits the gasifiers through the gas outlet at the lower part of the gasifiers. Typically, producer gas is a mixture of combustible gas such as CO, H2, and CH4 and non-combustible gas such as CO2 and N2 (Susastriawan, Saptoadi, &Purnomo, 2017). Producer gas has a lower heating value than the other gaseous fuels, but it can be manufactured with relatively simple equipment; it is used mainly as a fuel in most large industrial furnaces. Downdraft gasifier is one of the types of gasifier system and is the most suitable gasifier system in order to perform in lab-scaled gasifier. Downdraft gasifier is easy in fabrication and operation and attractive due to low tar content in producer gas. The gasifier has a sequence in the reactor itself. It is unrealistic to split gasifier into multiple zones, but to understand and differentiate the zones, separation of the process is involved. Those zones are drying, pyrolysis, partial oxidation and reduction zone.

The top zone is the Drying zone (or bunker section) in which occurs the conversion of moisture to water vapour during the drying process. Conversion takes place due to heat transfer between hot gases from the oxidation zone to biomass in the drying zone. Next is the Pyrolysis zone (or thermal decomposition zone) where in this zone biomass molecules are decomposed into condensable gases, tar, and char. Partial Oxidation (or combustion zone) is applied in the next phase where the volatile materials from biomass get oxided under exothermic chemical reactions and generate the heat with peak temperature with gaseous fuels like CO, H2, CO2 and H2O. In the final zone, the reduction zone is not only producing the producer gas, but also produces undesirable by-products such as tar.

In Malaysia, the government seriously wants to penetrate more renewable energy consumption for electricity generation sectors because in 2015, the estimation for potential electricity from renewable sources such as biomass and biogas is 330MW and 100MW. Even the electricity in Malaysia is majored by using gas rather than coal. In 2010, 59.1% of electricity generation was from gas and 34% was from coal.

## METHODOLOGY

To understand the overall gasifier system and improve the performance of downdraft gasifiers, the design of the current related system should be improved in order to propose the new design of gasifier. Due to the fact that the fuel material is rice husk, thus the methodology is based on an experimental set-up of rice husk gasifier unit. 7 gasifiers' set-up units have been found through reading of other literature as stated in Table 1.

In order to improve the performance of downdraft gasifiers, the basic design of the gasifiers has been modified. Various improvements on the basic design of the gasifiers have been done and reported by many researchers. Based on those works, the improvement can be classified as shown below.

### Design 1

In this work, the rice husk had been obtained from them/S Tulasi rice mill in the Limbasi village of Kheda in the state of Gujerat, India. The results obtained in this work is the fluidization properties of the materials, physicochemical properties of the rice husk and its char, electric power consumption, temperature profile, effect of equivalent ration (ER) on producer gas quality, effect of ER on gasifier performance, effect of catalyst on gasifier performance, and the effect of catalyst on flame temperature gas yield and high heating value (HHV).

The experimental setup as shown in figure 1 was separately made, where the reactor made of seamless pipe with total height is 1600mm and internal diameter is 210mm (Makwana, Joshi, Athawale, Singh, & Mohanty, 2015). The reactor is ignited using charcoal and the air will be blown for making the red hot charcoal. From the design setup, the screw conveyor set is separated from the reactor with the hopper as the holder. The reactor type is throat type and air supply flow from the bottom of the reactor.

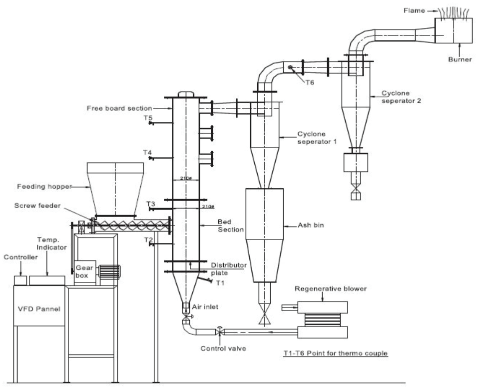


**Figure 1: Schematic of the Fluidized Bed Gasifier (FBG)**

(Source: Makwana, Joshi, Athawale, Singh, & Mohanty, 2015)

## Design 2

For this work, an experimental study was performed with the reactor under suction from throttled centrifugal blower. This test was conducted by placing each reactor under suction from centrifugal blower, throttled at its outlet to maintain desired pressure drop across the reactor. Fuel in the reactor was loaded at the top and no additional fuel was added as the reaction proceeded. The work had done experiments related on proximate analysis and HHV data of rice husk, ultimate analysis data of rice husk, producer gas flowrate as a function of specific gasification rate and etc. (M. Tiangco, M. Jenkins, & John, 1995)

This gasifying technology system had been performed at the University of California at Davies. Design of the gasifier was set and that the feeding is manually fed into the throat-less type of reactor. The air supply system being used flowed from the top open of gasifier. This system had also set the thermocouple from the top into the reactor.

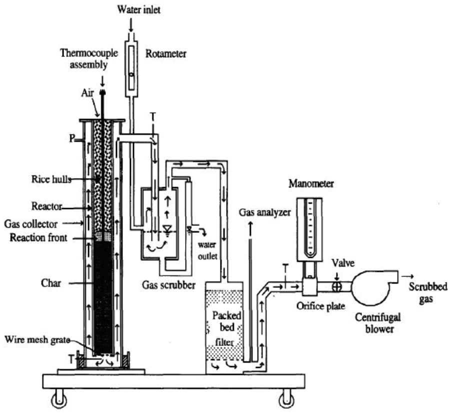


Fig. 2. Schematic experimental configuration of the gasifier system.

**Figure 2: Schematic Experimental Configuration of the Gasifier System**
(Source: M. Tiangco, M. Jenkins, & John, 1995)

## Design 3

The objective of this work focused on the syngas composition, gasification performance, power generation based on gas engine and generator. All the work had been done by using rice husk produced from rice mill in Chungnam Province in South Korea. The rice husk pellet produced by the Hanbyeol Corporation (Yoon, Son, Kim, & Lee, 2012).

All the parameters of the gasifier system were constructed with the reactor, gasifier, cyclone, scrubber, dust filter, boiler and engine as shown in Figure 3. In the feeding system, the hopper is located at the lower end of the system. They transfer the husk using pneumatic conveyor. Feeding rate is around 40 to 60 kg/h. Reactor is throat-less type and the air supply system is at the top of the reactor (Yoon, Son, Kim, & Lee, 2012).

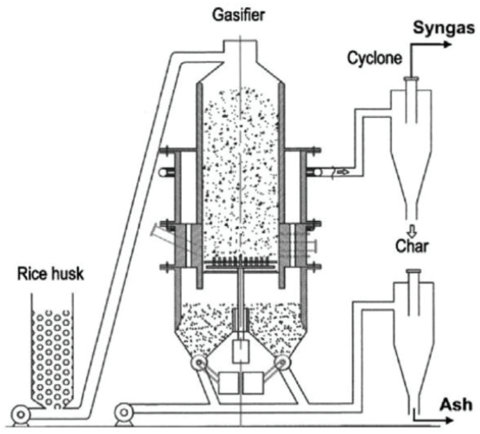


**Figure 3: Detailed Design of Fixed-bed Rice Husk Gasification System**

(Source:Yoon, Son, Kim, & Lee, 2012)

## Design 4

In this system, the work is developed and used suitable with the experiments needed which is compact on-line method for the measurement of tar plus suspended particulate matter (SPM). This is the improvement publication of work by Makwanaet. al. (2015). This work had been performed by the rice husk received from Bavla village, Anand district, Gujerat, India. The result on this work is to understand the effect of equivalence ratio, energy and cost analysis and the effect of addition of catalysts in terms of the effect of energy consumption for bed heating, in terms of the effect on producer gas composition, in terms of the effect on gas quality, and in terms of the effect on gasifier performance. (Thakkar, Makwana, Mohanty, Shah, & Singh, 2016)

Based on Figure 4, it shows the fluidized bed reactor which was made of seamless pipe. The air supply from the bottom of reactor and the feeding of rice husk is separated hopper with the screw conveyor. It is a throat type of reactor.

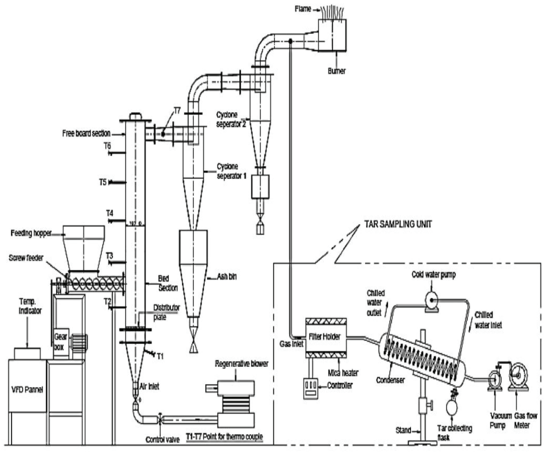


**Figure 4: Detailed Setup of Fluidized Bed of Rice Husk Gasification System**
(Source: Thakkar, Makwana, Mohanty, Shah, & Singh, 2016)

## Design 5

Circulating fluidized bed (CFB) biomass gasification and power generation system (BGPG) was designed and installed to archive power for a rice mill. This project had been demonstrated with the set up in Putian Huanguang Miye Ltd. located in Fujian Province of China. The results of the project were to archive temperature of the gasifier, gas production, and power output. (Yin, Wu, Zheng, & Chen, 2002)

Figure 5 shows that the hopper placed at the side of the reactor with the type of reactor is throat-less. The hopper is separated from the screw conveyor with the feeding rate 1500kg/h. The air supply is from the fan into the reactor (Yin, Wu, Zheng, & Chen, 2002)

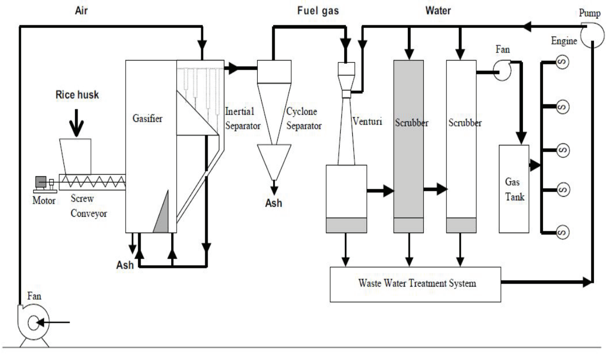


**Figure 5: Schematic of 1MW Rice Husk Gasification & Power Generation System**
(Source: Yin, Wu, Zheng, & Chen, 2002)

## Design 6

Throat-less rice husk had been developed for water pumping or energy generation using the downdraft gasifier system. The gasifier had been designed and developed at the University of California, Davis, USA. The results obtained from the experiments is the optimum value of specific gasification rate in reactor, optimum value of equivalence ratio, heating value of producer gas and cold gas efficiency for gasifier. (Jain & Goss, 2000)

The design had been stated in Figure 6 that the reactor is exactly throat-less while the air entry into the reactor as the supply is on the top of reactor and its feeding system is manually feeding from the opening of the reactor. The ignition material dropped some papers into the reactor by adding char over the grate with the aid of a blower.

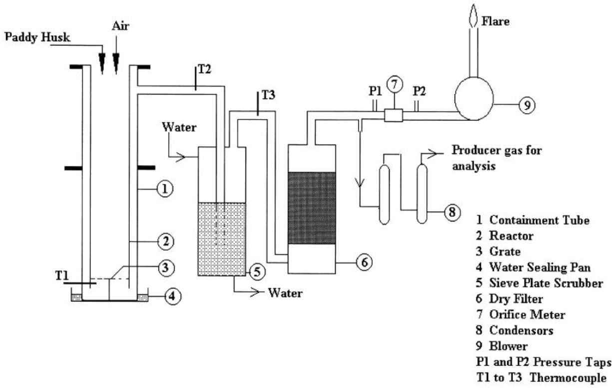


**Figure 6: Experimental Set-up of the Gasifier Unit**
(Source: Jain & Goss, 2000)

## Design 7

This work is an analysis of torrefied biomass for the gasification process. In the process, the rice husk pellet (RHP) had been torrefied using torrefaction system before the rice husk is being transferred for the next process of gasification. Focusing on the gasification process, the stacking of rice husk will be placed in the silo (act as hopper) that can be transferred into the gasifier through the screw conveyor. The valve functions by managing the quantity of rice husk transferred into the screw conveyor. Outcome of the work is in archiving the high value of chemical energy (exergy) of RHP and energy efficiency of the work. (Manatura, Lu, Wu, & Hsu, 2017)

In Figure 7, the gasifier had a separated hopper using Silo and connects with the screw conveyor and the throat type of reactor. Air had been supplied from the compressor that connects with the Pre-heater into the bottom of the reactor.

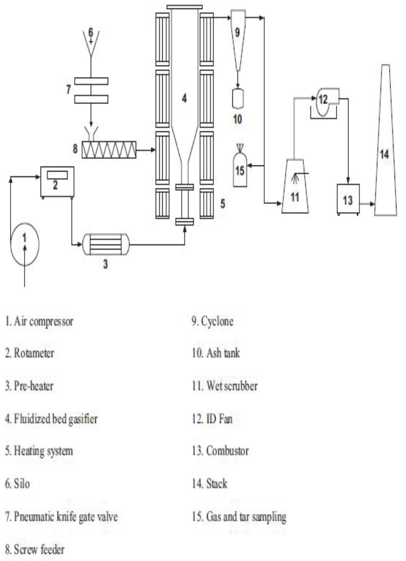


**Figure 7: Diagram of flow of the fluidized bed gasification system**

(Source: Manatura, Lu, Wu, & Hsu, 2017)

## RESULTS AND DISCUSSIONS

Overall, the design of gasifier had been stated in methodology with its specification. The selection of proper gasifier plays an important role in biomass gasification. Typically, the downdraft gasifier is designed for particular biomass feedstock. It makes the downdraft gasifier only suitable for intended biomass feedstock. The use of pelletized feedstock requires fuel pelletizing process that needs additional processing cost. To minimize the designing cost, a mathematical model can be applied prior to fabrication. Modelling result can be used as a guideline for selecting a suitable gasifier for intended biomass feedstock. This future work aims to develop the downdraft gasifier which is compatible for direct use of low-density feedstock.

Thus, there are some of the discussions for all the design and the proposal of a new design.

## Design 1 and 4

In this work (Figure 1 and 4), both had been done in the similar method as the reactor and inlet method. However, the use of motor or any gear box with the controller produce an external energy to run screw feeder should be reconsidered either it produces more external energy or it is sustainable to proceed with the system. The system for this work also runs in Fluidized Bed type gasifier which the system is not suitable to be run. This is due to required systems in small-scale or lab-scaled gasifier where that classed in downdraft system in Fixed Bed type.

However, the hopper feeder and position of screw conveyor into the gasifier is a good process and continuous feeding is important to keep the gasifier system running continuously and unstoppable. Air supplies is also a good mechanism to work with when it is flowing from the bottom of the reactor.

## Design 2 and 6

In reference to figure 2, the hopper is unavailable where the rice husk was being placed in the reactor manually. This will cause a problem of continuous burning whereby this system will be unable to burn at a longer time. Design 2 system named as static bed (or “open core”) gasifier is suitable for small-scale but the system is still not conducive to work with. For the air supply system, the air flows from the top opening of the gasifier and is unable to measure the suitable quantity of air used in the systems. However, for design 6, the system of gasifier is using downdraft gasifier which is similar to the system requirement.

## Design 3

With the system, the transferring of rice husk will be done from the hopper at the other part outside of gasifier. The transferring agent is based on the pneumatic system. This is a good system to be performed in the gasifier.

However, syngas is produced from the reaction of biomass with the supplied air as a gasification agent from the top side (Yoon, Son, Kim, & Lee, 2012). This is also similar with the point in 3.2 whereby the quantity of air cannot be measured to archive perfect burning to perform the systems. The cost of manufacturing the pneumatic systems also should be considered.

### Design 5

This CFB gasification used is similar with Design 1 and 4 where the hopper and screw conveyor used are by running with the screw motor. Air supply system also flow the fans into the gasifier. Both mechanisms to run motor and fan should be reconsidered whether it produces more external energy or it is sustainable to proceed with the system. The project was unable to run. This is due to the system that required to be run is the downdraft gasifier but the system is in fluidized bed gasifier.

However, the hopper feeder and position of screw conveyor into the gasifier is a good process and continuous feeding is important to keep gasifier system running continuously.

### Design 7

With the system, it is performing bubbling fluidized bed system which is similar with design 1 and 4 whereby the system is not suitable to be run due to required systems is in small-scale or lab-scaled gasifier where that classed in downdraft system in Fixed Bed type. The use of motor or any gear box with the controller produces an external energy to run the screw feeder should be reconsidered whether it produces more external energy or it is sustainable to proceed with the system.

However, the hopper feeder and position of screw conveyor into the gasifier is a good process and continuous feeding is important to keep the gasifier system running continuously. Air supplies is also a good mechanism to work with when it flows from the bottom of the reactor.

### Design Recommendation

Of all the designs specified from Design 1 to 7, it is found that the inclusion of rice husk is one of the important factors in the gasification. Therefore, the design of the inputs is important to facilitate rick husk to move into the reactor during operation which should consider the place of inserting the materials. The gas produced in the system must be flowed to the top pipe of the reactor and appear at the gas outlet. The new design is created to have better design for continuous work (estimation in 2 hours or more). The design of product is stated as below.

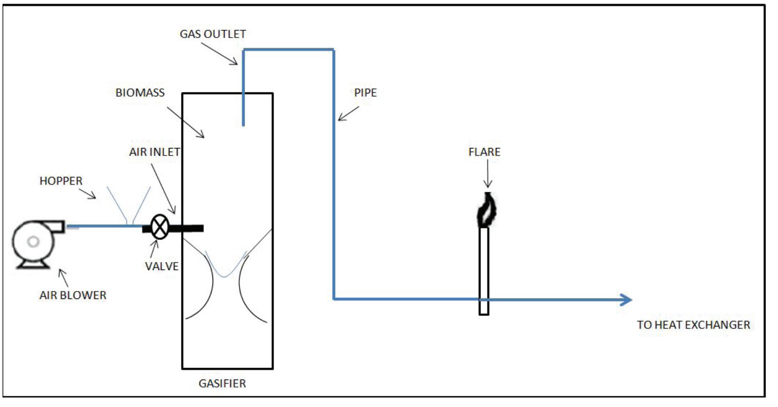


**Figure 8: Proposed Design of Downdraft Gasifier**

Inspired from the design that had been studied, the design proposed is to be made by parts where the inlet system, inter-reactor system, the outlet flow and the output of the gasifier.

For the inlet parts system, the air blower is being used as an air supply system plus the hopper was placed on the similar piping so that the rice husk will be placed in the hopper and flow together with the air. This method must be done in the right position. If the position of the hopper being place at the top, while the blower flow from side or bottom, the rice husk will not come into the gasifier but also will blow out of the gasifier. Hopper is a good mechanism to hold in the rice husk for a few hours. The mechanism was perfectly being used by the current machine. The hopper is made to stock the quantity of rice husk after the gasifier had been fully filled.

For the inter-reactor system, they need to be performed using downdraft gasifier with the lab-scaled. Downdraft gasifier is the system that can possibly produce tar free gas and higher fuel conversion rate. The reactor must be in throat type which could maximize mixing of gas in high temperature region.

Outlet flow been set to be at the top of the gasifier whereby the flow of the gas will be transferred for the output of the producer gas. The type of pipe use is GI pipe. For the output of gasifier, there is a head opening to show the flame of the producer gas.

This design will be a better idea to produce clean green energy by gasifier itself.

## CONCLUSION

The downdraft gasifier is suitable for small-scale biomass gasification due to its easy fabrication and operation. The output of producer gas and the gasification efficiency in the system are the output parameter that affected by some important parameters. The proper design and modification of downdraft gasifier minimize drawbacks which cause increasing performance of gasifier. All the parameters must be considered such as inlet systems, inter-reactor system, outlet flow system and the output of the gasifier. The use of blower and hopper help to maintain continuous feeding of feedstock into the reactor. Producer gas can be archive as an output. The proposed design is the outcome of this writing.

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