INDUCED-DRAFT RICE HUSK GASIFIER WITH WET SCRUBBER AND JET-TYPE BURNER: DESIGN AND PERFORMANCE

by Alexis T. Belonio and Ted Redelmeier

Gasification of biomass is becoming of interest to many for not only it is a versatile method of producing heat and power, but more so, it produces char as by-product which can be used as a material for soil amelioration and a means to sequester carbon. Among the different technologies used in the gasification of biomass, the moving-bed downdraft-type gasifier reactor is becoming popular among technology developers for it can be operated in a continuous-mode eliminating the need to reload fuel and re-start after 2 hours of operation. The induced-draft, which induces air to the reactor during gasification, is of more advantage over the forced-draft method for a number of reason. By induced-draft, the start-up of the gasifier is much simpler and shorter as compared with the forced-draft type gasifier. The gasifier, which is described in this brief paper, is the result of the developmental effort undertaken by the Carbon Neutral Commons (CNC) to come up with the design of a rice husk gasifier equipped with an induced-type source of power for heating application. The gasifier system is equipped with wet scrubber, packed-bed filters, and tar strippers to clean and cool the gas thus minimizing tar problem commonly encountered in other gasifier systems.

Figure 1. The Induced-Draft Rice Husk Gasifier with Wet-Scrubbing Unit and Jet-Type Burner during Operation.

(a) (b)

Figure 2. Other Views of the Reactor: (a) Reactor and Water Bin; and (b) Wet Scrubber, Tar Drippers, and Packed-Bed Filter.

As shown in Figure 1 above, the gasifier consists of three major components such as the fuel reactor, the gas conditioning device and the gas burner. The fuel reactor (Fig. 2a) is where rice husk is partially burned to produce combustible gases rich in carbon dioxide (CO), hydrogen (H_2), and methane (CH_4). The gas conditioning device (Fig. 2b) is where impurities like sooth, particulates, and tars are removed from the gas. And, the gas burner is where the gas generated is combusted producing heat. As given in Table 1, the fuel reactor has a diameter of 60 cm and a height of 1.20 m. It has a 5cm-thick insulation made of a mixture of cement, sand, and rice husk char at a proportion of 1:2:2. The air enters from the top of the reactor with the use of a suction blower and the gas exits from the bottom end of the reactor. An 80cm-diameter and a 1.6m-high outer cylinder encloses the insulated reactor. The gas exits at the annular space between the insulated reactor cylinder and the outer cylinder casing. An 8-pocket-type char disposal mechanism is used to gradually remove burned rice husks from the reactor dropping them into a water-bin container to quench the burning of char keeping it from burning further thus preventing the char from turning into ash and, at the same time, to seal the bottom of the reactor. The gas conditioning device, on the other hand, consists of a 10cm-wide by 1m-long cross-flow water scrubber and a 60cm-diameter by 40cm-thick packed-bed filter made of 3- to 6- mm diameter gravel. Four 10cm-diameter by 1.2m-high tar drippers are used to remove the tar as it passes the cylinders. Inside the cylinders are circularly arranged parallel vertical plates to allow the tar to stick on the plates as it travels from one cylinder to the other. Before the gas reaches the suction blower, another filter having 40-cm diameter and 50-cm bed thickness is used for final screening of the gas to further remove water and residual tars. A 0.76-kW ring blower is used to suck the gas from the reactor to the gas conditioning device and to push the cleaned gas to a 10cm-diameter jet-type burner.

Table 1. Design Specifications of the Induced-Type Rice Husk Gasifier with Wet Scrubber and Jet-Type Burner.

Reactor	Downdraft 0.60m D x 1.20m H
Char Grate	8 pcs semi-circular pocket-type rotating grate
Conditioning Unit	Cross-flow wet scrubber 10cm D x 1m H, 60cm D x 40cm T filter with 3- to 6-mm D gravel, 3 pieces of tar stripper 10cm D x 1m H, and 2^{nd} filter 30cm D x 50cm T made of rice husks
Burner	Jet-type 10cm D x 0.6m L
Blower	1 unit 0.7 kW, 220 volt ring blower
Pump	1hp, 220 volt centrifugal pump

The rice husk (Fig. 3) moves down upon turning the char disposal mechanism scraping off the char. As the char is scraped off from the bottom end of the reactor, fresh rice husk is fed from the top end. The gas produced is allowed to pass through the cross-flow wet scrubber using water as medium for washing and cooling. After which, the gas enters the packed-bed filter screening schematic of the process of operation of the gasifier unit is illustrated in Figure 4 below. As shown, rice husk is converted into gas in the reactor during combustion.

Figure 3. The partial burning of rice husk in the reactor during the operation of the gasifier.

The reactor operates

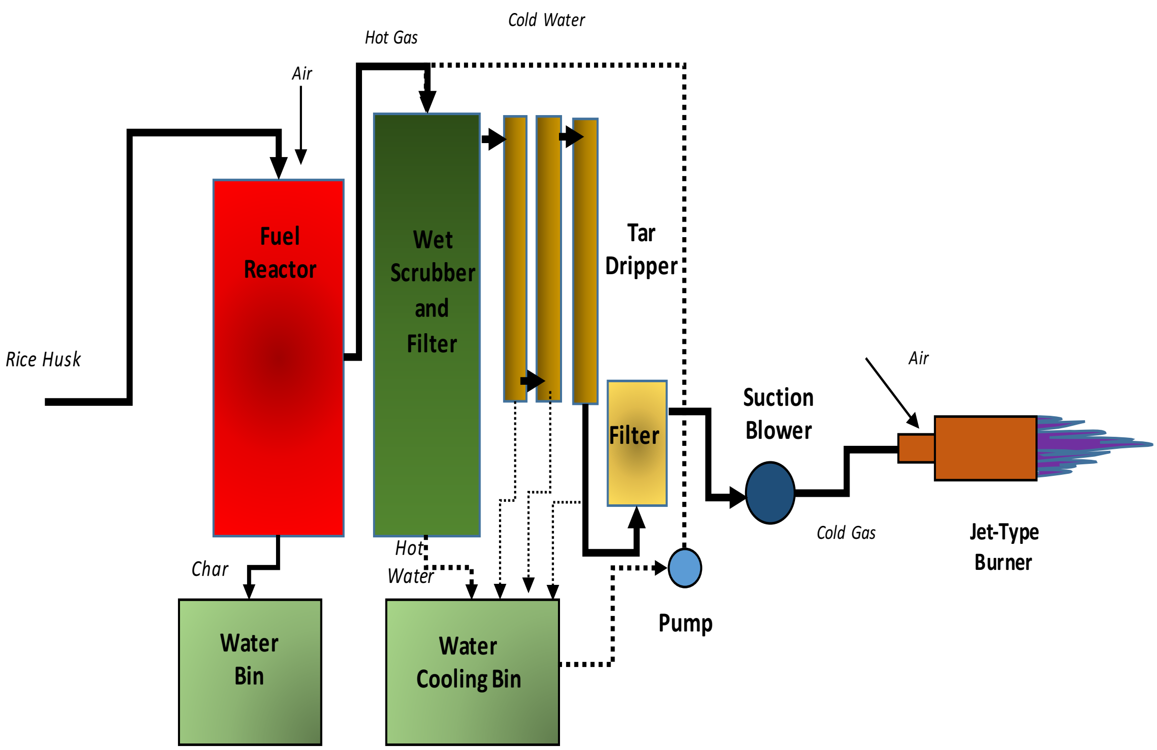

Figure 4. Schematic of the Process of Operation of the Gasifier.

on a moving-bed downdraft-mode gasification principle, in which the bed of partially-burned out tars and particulates. The gas is then allowed to pass through a series of tar strippers to separate the water. Furthermore, the gas passes again through the second packed-bed filter, which is made of rice husks as filter materials, to further filter tars and particulates before it is finally pushed into the jet burner. The gas mixes with air in the burner temperature measurement using shielded thermocouple wire recorded 412° to 800°C fuel bed temperature, and 123° to 186°C for the gas leaving the reactor. After leaving the wet scrubber and the tar stripper, gas temperature drops to a range 51° to 60°C. The temperature of water measured at the scrubber outlet ranges from 40° to 52°C. through the suction created by the jet burner producing blue flame when ignited. The water bin primarily quenches the burning char keeping it from turning into ash and, secondarily seals the bottom of the reactor keeping the gas from escaping. The water cooling bin, on the other hand, circulates the water in the bin to the wet scrubber. Water is added into the bin from time to time during operation to prevent the bin from overheating. The tar collected from the water cooling bin is allowed to flow to the reactor water bin through a pipe for it to be absorbed by the char preventing it from accumulating.

Performance tests of the gasifier unit showed that rice husk can be successfully gasified producing gas that is blue flame in color when ignited. As shown in Table 2 at the right, rice husk with 13 to 15% moisture requires a start-up time of 4 to 10 minutes before combustible gas is produced. Rice husk fuel consumption is at 35 to 42 kg per hour giving a specific gasification rate of 125 to 150 kg/hr-m^2. Using an induced blower for the system provides an air flow rate of 12.2 to 21.9 m^3/hr. The computed superficial velocity at the reactor bed ranges from 1.19 to 2.16 cm/sec. Air-fuel ratio is at the range of 0.43 to 0.65 kg air/kg of fuel. During the test, temperature measurement using shielded thermocouple wire recorded 412° to 800°C fuel bed temperature, and 123° to 186°C for the gas leaving the reactor. After leaving the wet scrubber and the tar stripper, gas temperature drops to a range 51° to 60°C. The temperature of water measured at the scrubber outlet ranges from 40° to 52°C.

Table 2. Performance of the Gasifier Unit with Dry Scrubber and Pipe -Type Burner Attached.

Feedstock	Rice Husk
Moisture Content	13 to 15%
Start-Up Time	4 to 10 min
Fuel Consumption Rate	35 to 42 kg per hour
Specific Gasification Rate	125 to 150 kg/hr-m^2
Air Flow Rate	12.2 to 21.9 m^3/hr
Superficial Velocity	1.19 to 2.16 cm/sec
Air-Fuel Ratio	0.43 to 0.65 kgair/kgfuel
Temperature	
Reactor	412° to 800°C
Gas After Leaving the Reactor	123° to 186°C
Gas Leaving Tar Dripper Scrubber	51° to 60°C
Water Leaving the Scrubber	40° to 52°C

Measurement of the composition of gas (Fig. 6) emitted from the gasifier using Amperis Transdox Gas Analyzer, Table 3 showed that the amount of carbon monoxide (CO) gas obtained ranges from 12.3 to 13.07 %; whereas, that of hydrogen (H_2) and methane (CH_4) gases obtained range from 8.02 to 8.23% and 3.82 to 3.92%, respectively. Carbon dioxide (CO_2) and oxygen (O_2) gases obtained were at the range of 5.34 to 5.84% and 5.80 to 5.87%,

Figure 6. Gas Composition Measurement Using the Amperis Transdox Gas Analyzer.

respectively. It can be observed from the result that the lower heating value of gas obtained in this gasifier model is only at the range of 3.86 to 4.09 MJ/m^3.

Table 3. Composition of the Gas Produced from the Gasifier.

Gas	Composition
Carbon Monoxide (CO)	12.13 to 13.07 %
Hydrogen (H_2)	8.02 to 8.23 %
Methane (CH_4)	3.82 to 3.92 %
Carbon Dioxide (CO_2)	5.34 to 5.84 %
Oxygen (O_2)	5.80 to 5.87 %
Lower Heating Value	3.86 to 4.09 MJ/m^3

Samples of 20-liter capacity plastic bag were obtained for testing in the analyzer during the tests.

It can be concluded that the gasifier unit performs satisfactorily as per design employing wet scrubbing technique and fueling a jet-type burner. One person is required to operate the gasifier to load rice husk fuel and to discharge char. The gasifier has short start-up time and is able to operate on a continuous mode. The char disposal mechanism is not tedious to the operator because it only requires swinging the lever to 45 degrees in forward and backward motions. During operation, the bed of rice husk inside the reactor was also observed to have an even downward movement every time char is discharged. Using wet scrubber, filters and tar drippers effectively drops the temperature of and removes the tars from the gas thereby not harming the blower. Tar production is well managed in this system by diluting it with the water from the char water bin. Actual testing of the gasifier isrecommended for boiler heating in food industries, drying of grains, and other similar applications using a jet-burner to further assess the usefulness of this technology in larger applications.

For detail information, contact;

www.carbonneutralcommons.org
Released: December 8, 2017