Design and Performance for 14kW Downdraft Open Core Gasifier

Myat Thu Htet
Lecturer, Department of Mechanical Engineering, Technological University (Dawei), Myanmar

DOI: 10.29322/IJSRP.8.7.2018.p7946
http://dx.doi.org/10.29322/IJSRP.8.7.2018.p7946
E-Mail: mthuhtet@gmail.com

Abstract- Gasification is a thermo –chemical conversion process in which biomass reacts in oxygen/air deficient atmosphere to produce a gaseous fual mixture.The result of gasification is the producer gas, containing carbon monoxideand hydrogen as main combustible gases.Producer gas can be used by mixing with air in internal combustion engines and in furnances for thermal applications. Gasifier is a reactor in which the gasification process is carried out. The objective of this paper is to study design and operation analysis of down-draught, open core gasifier which uses rice husk as gasification fual. Its output is about 14 kW and the design consideration is intended for YSD2100 Diesel Engine. In this paper, the components of rice husk and their operations are studied. Moreover, reactor designs, gasifier efficiency and power output calculation are included.Besides, the maintenance and safety techniques, troubles and their solutions are also discussed.
Index Terms- Gasification, reactor, rice husk, Diesel Engine

I. INTRODUCTION

The demand for renewable sources of energy is increasing due to an elevated concern about global warming, climate change and the decline of fossil fuel reserves. Compared with other renewable energy resources, biomass is huge. Its annual production rate is high and it is geographically widespread throughout the world. In general, paddy, or rice, is one of the earths' most prolific crops. Rice husk is a residue from rice farming and is considered an agricultural waste. Rice husk can be treated as energy sources,a new kind of renewable resource, while the most commonly used petrified fuels at present are energy mills can be more than self-sufficient in electric power. Thus the development of rice utilization can be positive effect on the economics of rice production and consuming countries. However, it appears that no producer gas has yet been developed to produce a clean, tar-free gas from uncarbonized solid fuels such as agricultural residues, designs have been proposed and tested to solve this problems.Although the production of gas needs a certain skill, its principal advantage is that a solid fuel is turned into a gaseous fuel,which can be used in engines.

II. GASIFICATION TECHNOLOGY

A.Gasification Reactions

Producing gas from biomass consists of the following main reactions, which occur inside a biomass gasifier.

Drying: Biomass fuels usually contain 10%–35% moisture. When biomass is heated to about 100 °C, the moisture is converted into steam.

Pyrolysis: After drying, as heating continues, the biomass undergoes pyrolysis. Pyrolysis involves burning biomass completely without supplying any oxygen. As a result, the biomass is decomposed or separated into solids, liquids, and gases. Charcoal is the solid part, tar is the liquid part, and flue gases make up the gaseous part.

Oxidation: Air is introduced into the gasifier after the decomposition process. During oxidation, this takes place at about 700–1,400°C, charcoal, or the solid carbonized fuel, reacts with the oxygen in the air to produce carbon dioxide and heat.

$$C + O_2 \rightarrow CO_2 + \text{heat}$$

Reduction: At higher temperatures and under reducing conditions, that is when not nough oxygen is available, the following reactions take place forming carbon dioxide, hydrogen, and methane.

$$C + CO_2 \rightarrow 2\,CO$$
$$C + H_2O \rightarrow CO + H_2$$
$$CO + H_2O \rightarrow CO_2 + H_2$$
$$C + 2H_2 \rightarrow CH_4$$

B. Types of Gasifiers

Several types of gasifiers are currently available for commercial use: counter-currentor up draft fixed bed, co-current fixed bed or down draft, fluidized bed, entrained flow, plasma, and free radical. Temperature and pressure operating conditions as well as residence time are key factors in determining the natureand quality of the produced fuel gas. Gasifiers have been designed in various configurations. Based on solid fuel combustion, gasification reactors can be divided into three main categories: fixed bed gasifiers (updraft and downdraft), fluidized bed gasifiers and the less established entrained bed gasifiers.Detailed reviews of gasifier options are available in the international literature. Various biomass gasification designs have been developed during the past two decades. Fixed bed gasifiers are mainly used in the small-scale range, whilst for larger scale fluidized bed gasifiers are proposed. Two different types of fixed bed gasifiers were originally developed: updraft and downdraft gasifiers. In updraft gasifiers, the gasification agent is introduced at the bottom and the fuel gas flow is upwards counter-current to the biomass, which is fed from the top. The fuel gas leaves the gasifier at the top and the ash is discharged at the bottom. Several zones are created in updraft fixed bed gasifiers, which are starting from the top – the drying, the pyrolysis, the reduction and the oxidation zone. The temperature is increasing from the top to the bottom. The tars are produced mainly in the pyrolysis zone and leave the gasifier together with the fuel gas. Since there is no zone above the pyrolysis zone that has a higher temperature to thermally destroy the tars, a high amount of tars is expected in the fuel gas.

The downdraft gasifiers can be classified of two types. Those having, throat type design (including choke plate) and those with open core design. Throat type gasifiers are used for biomass fuels with low ash and uniform size, while open core gasifiers can tolerate more variation in fuel properties like fuel moisture, size and ash content. Also smaller throat diameter means higher gas velocities at the oxidative and reduction zones. This reduces tars but increases dust loading. Large throat diameter causes an increase of tar in the gas stream due to by passing of the hot zone. Fuels with high ash content (e.g. rice husk)

C. Down draft or co-current gasifiers

The downdraft (also known as co-current) gasifier is the most common type of gasifier. In a downdraft reactor biomass is fed at the top and the air intake is also at the top or from the sides. The gas leaves at the bottom of the reactor, so the fuel and the gas move in the same direction. The advantages of downdraft gasification include

(a) Up to 99.9 percent of the tar formed is consume requiring minimal or no tar cleanup.
(b) Minerals remain with the char/ash, reducing the need for a cyclone separator.
(c) Proven, simple and low cost processIn downdraft gasifiers,

The disadvantages of downdraft gasification are

(a) Requires feed drying to a low moisture content (<20%)
(b) Producer exiting the reactor is at high temperature.
(c) Requires secondary heat recovery system.
(d) 4-7 percent of carbon remains unconverted.

As a result, the mixture of gases in the exit stream is relatively clean. The position of the combustion zone is thus a critical elementin the downdraft gasifier, its main advantage being that it produces gas with low tar content, which is suitable for gas engines.

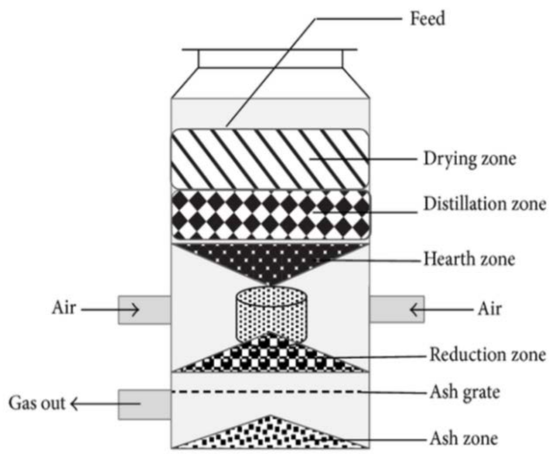

Figure1. Down Draught Gasifier

C. Composition of Rice Husk Fuel

Composition of Rice Husk Fuel depends upon types of rice and different moisture content.This composition can be determined by proximate and ultimate analysis.

Table1. Typical Proximate Analysis of Rice Husk (Percentage by weight)

Reference	Moisture	Ash	Fixed carbon	Volatile matter
P.A. Hicks	11.51	17.49	14.64	56.35
P.V.Grover	0	19.5	19.9	60.6
I.E.Cruz	0	23.2	15.3	61.5
Kaupp	9.8	23.0	12.5	54.7
	10.1 -12	15.8-23.0	12.7-17.4	56.4-69.3

Table2. Various Ultimate Analysis of Rice Huck (Percentage by weight)

Reference	C	H	O	N	S	Ash	Moisture	Heating Value(MJ/kg)	
								LHV	HHV
P.A Hicks	35.49	4.56	30.44	0.51	little	17.49	11.51	13.1	14.7
P.D. Grover	39.0	4.9	33.97	0.53	<0.01	21.6	10.1 →12	13.4	15.3
I.E. Cruz	35.6	5.2	35.8	0.2	−	23.2	0	14.5	14.5

Table3. Main three successive stages of biomass gasification

Gasification stage	Reaction formula	Reaction number/Reaction type	Reaction heat (kJ/Kmol)
Stage I: Oxidation and other exothermic reaction	$C+½O_2 \rightarrow CO$	(1)Partial oxidation	+110,700
	$CO+½O_2 \rightarrow CO_2$	(2)CO oxidation	+263,000
	$C+O_2 \rightarrow CO$	(3) Total Oxidation	+393,790
	$C_6 H_{10} O_5 \rightarrow xCO_2+yH_2O$	(4) Total Oxidation	>>0
	$H2+½O_2 \rightarrow H2O$	(5) Hydrogen Oxidation	+ 241,820
	$CO + H_2O \rightarrow CO_2+H_2$	(6) Water-gas shift	+41,170
	$CO + 3H \rightarrow CH4+H2O$	(7)Methanation	+206,300
Stage II : Pyrolysis	$C_6H_{10}O_5 \rightarrow C_xH_z+ CO$	(8) Pyrolysis	<0
	$C_6H_{10}O_5 \rightarrow C_nH_mO_v$	(9) Pyrolysis	<0
Stage III : Gasification (reduction)	$C+ H_2O \rightarrow CO+H_2$	(10) Steam gasification	-131,400
	$C+ CO_2 \rightarrow 2CO$	(11) Boudouard reaction	-172,580
	$CO_2+ H_2 \rightarrow CO+H_2O$	(12) Reverse water shift	-41,170
	$C+ 2H_2 \rightarrow C H_4$	(13) Hydrogenation	+74,900

III. METHODOLOGY AND DESIGN CALCULATION

A. Reactor Design Consideration

A typical rice husk gasifier has the following operational chatacteristics:
(a) A fuel is used which has a high natural ash content (15% - 23% by weight)and a low bulk density (100 kg/m^3)
(b) A gas output of 200 Nm^3/hr is achieved in large diameter furnace (1.5m)
(c) The residue after gasification amount of 30% − 40% of the initial volume of feedstock and 25% − 35of its initial weight. An effective continous ash removal system is therefore required.
(d) The low bulk density of rice husks necessitates either a very large hopper of a mechanism for continous feeding. Three parameters which influence rice hush gasification the most are following;

- Diameter of the reactor
- Continous ash removal
- Superficial gas velocity

B. Calculation of the Power Output of Producer Gas Engine

The gasifier will be designed for YSD2100 Diesel Engine. The specification of YSD 2100 Diesel Engine and Modified Gas Engine are shown in Table 4.

Table4. Specification of YSD2100 Diesel Engine and Modified Gas Engine

1	Model	YSD2100	Modified Gas Engine
2	Type	Vertical, Water-cooling, Four stroke direct combustion chamber	
3	Number of cylinder	2	2
4	Bore (mm)	100	100
5	Stroke(mm)	118	118
6	Compression ratio	18 : 1	10 : 1
7	Total displacement (mm)	1.854	1.854
8	Firing Order	1− 2	1− 2
9	Rated power (KW)	22.4 ~ 26.5	12.5~ 13.7
10	Cooling Method	Force water cooling	
11	Minimun specific fuel consumption at full load	≤240.7 (g/kW.h)	35.46 kg/hr

ISSN 2250-3153

Maximum air + gas intake into the engine cyliner = $\frac{½ \times rpm \times Vf}{60\times1000} = \frac{½\times2250\times1.854}{60\times1000}$ = $0.03476 m^3/s$
Air/gas ratio by volume = 1: 1.225
Maximum gas intake = $\frac{1.225}{2.225} \times 0.03476 = 0.01914 m^3/s$
The real gas intake is $0.1914\times \eta_v$ in which η_v is volumetric efficiency of the engine.
For a well designed and clean air inlet manifold, η_v can be taken as 0.8.
The real gas intake isQ_g is $0.01914\times 0.8 = 0.01531\ m^3/s$
The heating value (H_g) of the rice husk gas is taken as 4184 kJ/ m^3
Therefore thermal power in the gas is :
$P_g = 0.01531 \times 4184 = 64.057$
For a compression ratio of 10: 1, the efficiency can be estimated as 25 percent.
Therefore the maximum mechanical output of this engine is:
P_M maximum = $64.057 \times 0.25 = 16.01425$ kW = 21.475 HP
The efficiency of generator can be estimated as 85 percent.
The maximum electrical output is therefore P_E maximum = $16.01425 \times 0.85 = 13.612 \approx 14$ kW
14kW output Down – draught Open Core Gasifier Design Calculation
Rice Husk Used for electricity
Thermal efficiency of the gasifier is taken as 50%
Thermal power consumption (full load) = 64.057/0.5 = 128.114 kW
Heating value of rice husk (11% to 20%MC) : 13000kW/kg
Rice husk consumption of gasifier; $G_m = \frac{128.114\ kJ/s}{13000 kJ/kg}$ = 35.46 kg/hr
So the installation under consideration uses = $\frac{\mathrm{Gm}}{PE\ \mathrm{max}}$ = 2.51 kg/kWh
2.51 kg of rice husk to produce 1kWh elictricity.

C. Reactor Design
To calculate reactor diameter, one important imperical formula is
$D_R = 1130 \times G_m/q$ where D_R is the diameter of reactor
q = intensity of gasification or specific gasification rates taken as (110 ~ 210) $kgm^{-2}h^{-1}$
Gm is the rice husk consumption in kg/hr
Therefore reactor diameter (D_R),
For q = 110 $kgm^{-2}h^{-1}$, $D_R = (1130\times 35.46)/110 = 364.27$ mm
For q = 210 $kgm^{-2}h^{-1}$, $D_R = (1130\times 35.46)/210 = 190.808$ mm
Therefore diameter of reactor should be within 190.808 ~ 364.27 mm
The height of the gasifier can be determined by the following formula, H = D + 1.5D
where H = height of the gasifier and D = diameter of the gasifier
Therefore height of the gasifier (H),
For q = 110 $kgm^{-2}h^{-1}$, H = 364.27 + (1.5 ×364.27) =910.675 mm
For q = 210 $kgm^{-2}h^{-1}$, H =190.808 + (1.5 ×190.808) =477.02 mm
Therefore height of reactor should be within 477.02 ~ 910.675 mm

D. Gasifier Efficiency
A useful definition of the gasification efficiency if the gas is used for engine applications is:
$$\eta_m = \frac{\mathrm{Hg} \times \mathrm{Qg}}{\mathrm{Hs} \times \mathrm{Ms}} \times 100(\%)$$
In which:
η_m = mechanical efficiency of gasification (%)
H_g = heating value of the rice husk gas (kJ/m³),
Q_g = volume flow of gas (m³/s)
H_s = lower heating value of gasifier fuel (kJ/kg)
M_s = gasifier solid fuel consumption (kg/s)
$$\eta_m = \frac{4184\times0.01531}{13000\times0.00985} = 0.50025 = 50\%$$
Depending on type and design of gasifier as wellas on the characteristics of the fuel η_m may be changed.
Based on the observation, it was decided that a controlled continuous ash removal system is necessary for reliable continuous gasification of rice husks. When dealing with a difficult fuel such as rice husks, it is very important to eliminate factors that may influence the performance of a grate, but are not caused by the design of the grate. For instance,even a well- designed grate will not help if the rice husk fuel bed above the grate cake. A good ash removal system should meet the following criteria:

(a) It must remove the char in any form

(b) The rate of ash removal must be controllable.

(c) Because force feeding of rice husks into the firebox column is one option with regard to overcoming gravity flow problems and channel formation, the ash removal system should be able to remove densified char.

(d) The design should be simple.

IV. CONCLUSION

In this paper, the author approaches the open core rice husk gasifier from the point of mechanical view.Final output of the gasifier is about 14kW. Reactor diameter is 35.6 cm. Height of the gasifier is 61 cm. Gasifier efficiency is 50 percent. Gasifier is needed to maintain one time in one or two weeks.So the author design the movable parts to install easily. Moreover the author describes the maintence and operation stages to obtain more efficiency and to escape the operator from danger.The gasifier can be used by attaching 14 kW engine in many places such as irrigation pump ,ice plant,oil mill, tractors and small industries.

V. DISCUSSION AND RECOMMENDATION

Analyze and understand all the provided review comments thoBy using gasifier, rual areas can be obtained many benefits as follows:

- With electric power and available of water, there are possibilities for irrigation of rice fields or other crops.
- With power and light, small industries can grow and increase earning for people.
- Electric power will improve agricultural can grow and increase earning for people.
- Electric light means a lot for adult education since the daylight hours must be used for work in the fields.
- With light and power, small clinics can be made possible for improvement of health.

The main problems of rice husk gasification system can be summarized as follows

- Tar formal during the gasification process reach the engine and the technology of tar removal has to be improved.
- System maintence is time consuming and costly.
- The water consumption for the existing gasification system is high.

In the design, reactor diameter can save for required power and it may be minimum diameter for economy. The location of heat exchanger is very important.The best and suitable position is between the reactor exist and ash flushing tube. In dry filter design, good absorption materials are used and have been designed to enable the bedmaterial to be replaced easily and cheaplyroughly. An attempt should be made to install as much tar – absorbing fibre plates as possible in the gas storage tank so that tar is really reduced to a minimum before the gas reaches the engine. Producer gas is poison gas so the operator should take care of his health. In this paper, studies on the gasification of rice husk and producer gas is used in internal combustion engine have shown encouring results as (a) 100% diesel fual can be replaced successfully by producer gas (b) generator can produced about 14 kW driving with converted YSD2100 Diesel Engine (c) producer gas engine can be applied commercially in near future.It can be expected that the reliable, efficient and economical rice husk gasifier will be operated in rual area of Myanmar by using as refrance on this paper.Further research will be continued to improve the engine gasifier system.

REFERENCES

[1] AV Bridgwater "THERMAL CONVERSION OF BIOMASS AND WASTE " , Bio-Energy Research Group, Aston University, Birmingham B4 7ET, UK

[2] Bobby Abharam,‘‘ Presentation on Gasifier Based Rubber Drying System’’,Paramount Enviroenergies,Pvt Ltd.

[3] Grover, P.D., " BiomassThermo- Chemical Characterization for Gasification", Biomass Research Laboratory, Chemical Engineering Department Indian Institude of Technology,Delhi (1989) "

[4] Hicks, P.A., FAO Bankok, "Rice Husk Gasification Technology In Asia" , (RAPA Publication: 1991/2)

[5] Ibrra,E. Producer "Gas Technology For Rual Application" , FAO Agricultural Services Bulettin 62, Philippine.

[6] E. H. Miller, "A note on reflector arrays (Periodical style—Accepted for publication)," *IEEE Trans. Antennas Propagat.*, to be published.

[7] Kaupp, Albrecht., Gasification of Rice Husk, Theorey And Praxis, Isbn3 -528-02002-4(1984)

[8] I.E.Cruz, " Producer Gas Technology For Rural Application ",Manager,Philippine National Oil Company,Energy Research Centre,Philippine

[9] http://cturare.tripod.com/bio.htm

[10] http://www.fao.org/docrep/t0512e/T0512e09.htm