AGRICULTURAL WASTE GASIFIER STOVE

[1]RAVI S.SANADI, [2]SAGAR B.PHADATARE, [3]SALEEM I.MULLA

[1,2,3]Mechanical Engineering Department K.L.E's Kle College Of Engineering And Technology, P.B.No. 16 Banantikodi Road Chikodi-591201

E-mail: ravisanadi@rediffmail.com, sagarphadatare123@gmail.com, saleemimulla@gmail.com

Abstract- The Agricultural waste Gasifier stove is a device for domestic cooking utilizing agricultural waste as a fuel. The stove is designed to burn agricultural waste using limited amount of air for combustion to produce a luminous blue flame, which is almost similar to that of the LPG stove. The Agricultural waste Gasifier stove follows the principle of producing combustible gases, primarily carbon monoxide, from agricultural waste by burning it with limited amount of air. The wastes are burned just enough to convert the fuel into char and allow the oxygen in the air and other generated gases during the process to react with the carbon in the char at a higher temperature to produce combustible carbon monoxide(CO), hydrogen(H_2), and methane(CH_4). Other gases, like carbon dioxide (CO_2) and water vapor (H_2O) which are not combustible, are also produced during gasification. By controlling the air supply with a small fan, the amount of air necessary to gasify Agricultural waste is achieved. The problem on forest denudation facing the country combined with the need for fuel for cooking requirement, there is a need for us to look for alternative biomass fuel, other than wood like Rice husk, Bagasse, Wheat husk, Grass, Ground Nut husk etc, that can be used for cooking.

Keywords- Gasifier, Agricultural Waste, LPG, Producer gas.

I. INTRODUCTION

The Agricultural waste gas stove is a device for domestic cooking utilizing Agricultural waste as a fuel. The stove is designed to burn Agricultural waste using limited amount of air for combustion to produce a luminous blue flame, which is almost similar to that of the LPG stove.

Liquefied petroleum gas (LPG) is one of the conventional sources of fuel for cook stoves in the India. The use of LPG as source of fuel is common both in the urban and in the rural areas, particularly in places where its supply is readily accessible. The main reasons why LPG is widely adopted for household use are it is convenient to operate, easy to control, and clean to use because of the blue flame emitted during cooking.

However, because of the continued increase in the price of oil in the world market, the price of LPG fuel had gone up tremendously and is continuously increasing at a fast rate. At present 14.2 kg LPG, that is commonly used by common households for cooking, costs as high as Rs. 325 per tank in urban areas or even higher in some places in rural areas.

For a typical household, having four children, one LPG tank can be consumed within 20 to 30 days only depending on the number and amount of food being cooked. For the past years, gasifier stoves using wood as fuel has been developed in the countries like the India, US, China, Thailand, Sri Lanka, and other developing countries in Asia. These gasifier stoves produce a flammable gas by burning the fuel with limited amount of air. Wood gas stove was found promising to replace the conventional LPG stove.

This stove has a minimal problem on carbon dioxide emission during cooking since it produces primarily carbon monoxide. However, with the problem on forest denudation facing the country combined with the need for fuel for cooking requirement, there is a need for us to look for alternative biomass fuel, other than wood, that can be used for cooking.

1.2 Features of the Agricultural Waste Gasifier Stove

1. It is a good replacement for LPG stove, particularly in terms of fuel savings and quality of flame (i.e., luminous blue flame) produced during cooking.
2. It will significantly reduce the cost of household spending on conventional fuel sources such as electricity, kerosene, wood, and wood charcoal.
3. It will help to reduce the pollution in the air brought about by the excessive burning of wood and other biomass fuel in the traditional cook stoves.
4. It will help preserve the forest by reducing the cutting of trees for the production of wood fuel and wood charcoal thus, minimizing problems concerning drought during summer and flood rainy season.

II. GASIFIER STOVE AND ITS VARIOUS PARTS

2.1. The Gasifier Stove Reactor

The gasifier stove reactor is the component of the stove where Agricultural wastes are placed and burned with limited amount of 150 mm, outside diameter 200 mm and the height of the cylinder 600 mm. The outside cylinder is made of mild steel sheet, and inner cylinder is made of stainless steel sheet.

Space of 20 mm, where the glass wool is placed to serve as insulation in order to prevent heat loss in the gasifier at the lower end of the reactor is a fuel grate made of stainless steel material, which is used to hold the Agricultural wastes during gasification. This grate is positioned such that it can be inclined to easily discharge char after each operation. The grate is controlled by a spring or a lock to set it in proper position during operation. At the outside of the reactor are circular rings that hold the aluminum screen to keep the hands from accidentally touching the hot reactor during operation.

2.2 The Char Chamber

The char chamber serves as the storage for char produced after each operation. It is located beneath the reactor to easily catch the char that is falling from the reactor. This chamber is provided with a door that can be opened for easily disposal of char and it must be kept always closed when operating the gasifier. The char chamber is tightly fitted in all sides to prevent the air given off by the fan from escaping the chamber hence, minimizing excessive loss of draft in the system in gasifying the fuel. Four support rollers are provided beneath for the chamber to support the entire stove and for proper handling.

2.3 The Fan Assembly

The fan assembly is the component of the stove that provides the air needed by the fuel during gasification. It is fastened on the char chamber to directly push the air into column of Agricultural waste in the reactor. The fan used for the standard model is 3-inch diameter axial-type fan, it has a rated power input of 16 watts using 220 volt AC line. A manually-operated rotary switch is used to control the speed of the fan which, in turn, controls the flow of gas to the burner during operation.

2.4 The Burner

The burner converts the gas coming out from the reactor to a bluish flame. It consists of series of holes, 5 mm in diameter, where combustible gas is allowed to pass through. The secondary holes located at the periphery of the burner are used to supply the air necessary for the combustion of gases. On top of the burner is a pot support that holds the pot in place during cooking. The burner is removable for easy loading of fuel into the reactor and is set in place during operation.

2.5 Agricultural Waste Gasification

Agricultural Waste Gasification can be fully understood if one has a thorough understanding of the characteristics of fuel itself as well as principal of gasification. The Agricultural wastes are the byproducts of crops.

Gasification is the process of converting fuel into combustible carbon monoxide by thermo-chemical reaction of the oxygen in the air and the carbon available in this material during combustion. In complete combustion of fuel, the process takes place with excess air. In gasification process, on the other hand, it is accomplished with excess carbon. In order to gasify fuel, about 30 to 40% of the stoichiometric air (4.7 kg of air per kg of fuel) is needed. Limited amount of air is introduced by a fan into the fuel column to convert waste into carbon-rich char so that by thermo-chemical reaction it would produce carbon monoxide, hydrogen, and methane gages, which are combustible when ignited. Basically, the gas produced during gasification is illustrated as below.

Combustion	$C+O_2 = CO_2$
Water Gas	$C+H_2O = CO+H_2$
Water Shift Reaction	$CO+H_2O= CO_2+H_2$
Boudouard Reaction	$C+CO_2 =2CO$
Methane Reaction	$C+2H_2 =CH_4$

Carbon monoxide, hydrogen, and methane are combustible gases while the carbon dioxide and vapor are not.

Table 2.1 Composition of Gases Produced from Gasifier

Gas	% composition
Carbon Monoxide, CO	18.6- 8.6
Hydrogen, H_2	21.5-8.7
Methane, CH_4	0
Carbon Dioxide, CO_2	9.5-12.6
Water, H_2O	18.0-21.1

2.5 Factors that Influence Gasification

1. Energy Content of Fuel – Fuel with high energy content provides better combustion.
2. Fuel Moisture Content – The moisture content of fuel also affects gasification. Husks with low moisture content can be properly gasified than that with high moisture. Freshly produced husks are preferred to use for they usually contains only 10 to 12% moisture. Husks with high moisture content should be dried first before they are used as fuel for the gasifier.
3. Size and Form of Fuel– Husks obtained from mill are difficult to gasify. Which require high pressure fan in order to be gasified.
4. Size Distribution of the Fuel – Rice husks mixed with other solid fuels are not suitable for gasifier operation. Not uniform fuel size distribution will result to difficulty in getting well-carbonized rice husks, which affects fuel gasification.
5. Temperature of the Reactor – Temperature of the reactor during gasification also affects the production of flammable gas. There is a need to properly insulate the reactor so that during gasification, flammable gas can be produced. Rice husk ash and refractory materials are good examples of materials effective in maintaining high temperature in the reactor for better gasification. Providing an annular space in a double core reactor is also an effective way in maintaining high temperature in the reactor.

2.6 Air Requirement for Gasification

The amount of air needed to gasify husks is limited than that needed to burn by direct combustion. The stoichiometric air requirement of husk is normally equivalent to 4.7 kg of air per kilogram of husks. At an air density of 1.25 kg/m^3, the volume of air needed for combustion is 3.76 cubic meter per kilogram of husks. In order to gasify husks, the amount of air

needed for gasification is about 30 to 40 % of the stoichiometric air. Therefore, the amount of air to gasify a kilo of husks ranges
from 1.128 to 1.504 m^3.

2.7 STOVE FABRICATION

Generally, the discussion below is applicable only when fabricating the rice husk gas stove in a small metal craft on a batch-method, producing six units of the stove per batch. Because of the limited availability of equipment in most small fabrication shops, a simple procedure was followed by the fabricator in fabricating the stove and is presented. Note that mass production in a large-scale manufacturing shop is quite different than in a small shop.

2.7.1Construction Materials

The agricultural waste gas stove, similar with other metal stoves, generally requires the following materials for its fabrication:

- Galvanized iron sheet, no. 20 or 18
- Stainless steel sheet no. 20 or GI sheet no. 16
- Stainless steel rod, 1/4-in. diameter
- Stainless steel screen mesh, 1/4 in.
- Hinges
- Door Lock
- Glass Wool
- Fan or blower
- Switch
- Rubber Shoe Cap

The galvanized iron (GI) sheet is used for the construction of the outer cylinder of the reactor and of the char chamber. Either GI sheet gauge 20 or 18 can be used, depending on the desired durability and on the estimated cost to produce the stove. The material usually utilized for the inner cylinder of the reactor is stainless steel sheet, either gauge 20 or 22. In order to reduce the cost of producing the stove, stainless steel sheet gauge 22 can be used without sacrificing the expected durability of the stove. Thicker GI sheet, i.e. gauge no. 16, can be another alternative in case the stainless steel is hardly available or is very expensive. The cost of the stove can be further reduced by minimizing the use of stainless steel for the inner reactor. For the burner assembly, the outer cylinder is usually made of GI sheet material with the same gauge as that of the reactor.

The inner cylinder, the part of the burner which is directly in contact with the flammable gases, generally requires the use of stainless steel because of its good resistance to heat. The pot support and the handle of the burner assembly including the frame for the char grate and the lever are also made of stainless steel material for better durability. On the other hand, the insulation of the stove is made of rice husk ash which is a good insulating material due to its high silica content. Rice husk ash is also very cheap since it can be obtained from the burned rice husks found either on road sides or in the field. Mixing the cement with rice husk ash, at a ratio of 1 part cement to 1 or 2 parts of rice husk ash, can effectively keep the insulation intact. A fan or a blower is used to provide the air needed for gasification. Fan and blower can be readily purchased from any electrical suppliers. A switch is used to regulate the amount of air delivered by the fan. It is connected with the electrical wirings of the fan for the latter to be easily switched OFF and ON during operation. Hinges and door locks are usually obtained from hardware suppliers. They are the type of hinges and locks commonly used for steel windows of houses.

2.7.2 Manpower Requirement

Fabricating six units of the gas stove will require two persons to finish the job within a week. This is considering all the needed materials for the fabrication are already purchased and delivered to the Shop. Also, the tools and equipment needed for fabrication are already available. In fabricating the stove, at least one of the two laborers must be skilled in fabrication job particularly in the welding of metal sheets. The other worker will serve as a helper to do the cutting of metal sheets and bars. If both of the welders are unskilled, this may have an effect on the quality of the finished product which may appear unattractive to the prospective buyers. Based on experience, fabricating the stove for the first time even with someone who can guide the step-by-step procedure would take a much longer time than when they have already produced several batches of the stove. It was experienced that during the first batch of producing the stove, the two persons can finish the entire batch of the stove unit within two weeks. During the later part of the production of the stove, the two workers can finish the same batch of the stove within one week only.

2.7.3 Tools and Equipment

The following are the basic tools and equipment needed in
the construction of the gas stove:

1. Tin Snip – This is a tool used for cutting metal sheets, especially for gauges 18 and above. For the husk gas stove, this is usually suited for cutting the materials for the inner and the outer reactors, as well as the ash or char chamber.
2. Shear Cutter – This tool is used for cutting thicker sheets of metal, especially gauge no. 16.
3. Bench Drill – This tool is used for drilling holes. The Tin Snip. The Bench Drill. Especially in the fabrication of the burner assembly, for the primary and secondary air. A bench drill provides a better accuracy when drilling several burners at a time or drilling thicker materials. Power hand drill can also be used for drilling holes. However, drilling of holes can only be done for one to two sheets at a time when using power hand drill.

4. Hammer – This is used in folding metal sheets to form them into a desired shape. The use of hammer is minimized when the materials are bent using a bar folding machine.
5. Arc and Oxy- Acetylene Welding Machines –
These equipment are used for fixing thick metal sheets together. Since a galvanized iron sheet no. 18 is used for the stove, the arc welding machine is used with the oxy acetylene welding, for welding metal parts together.
6. Roller – This tool is a locally made device used to roll metal sheets into a cylinder, particularly in making the inner and the outer reactors as well as all cylindrical parts of the stove burner. Although this is not as accurate as with the roller press, this device was found to serve the purpose of bending some materials in the production of the stove in small shops.
7. Pliers – This is used in holding pieces of the material, especially during welding, as well as in folding parts of the metal sheet to be provided with stiffeners.
8. Jigs – This is used to keep the parts firmly in place during the fabrication of the stove flange for the inner and the outer cylinder of the reactor. There are still other assembly tools such as screw drivers, wrenches, and pliers needed in the production of the stove. In large-scale production, the use of bar folding machine, roller bender, and bench shear can provide a more accurate and faster production of the stove. Producing in a large-scale manufacturing is believed to further reduce the cost of the stove per unit.

2.7.4 General Guidelines

The general guidelines in fabricating the rice husk gas stove are enumerated below. The succeeding section gives the specific step-by-sep procedure for finishing one unit of the stove.

1. Review the design drawing of the agricultural waste gas stove. Determine the various assemblies of the stove such as the fuel reactor, char chamber, and burner. Take note of the materials and the dimension of the various assemblies. Carefully study how these assemblies will be fabricated considering your own facilities and equipment. Always remember that parts of the stove should be made at a least possible cost for labor and electricity.
2. Prepare all the materials needed for the construction of the stove.
3. Make a layout of each of the different components of the stove on a metal sheet. For six units of the stove, two GI sheets and a sheet of stainless steel are needed. Make sure the use of the materials is maximized when making a layout for the stove parts. In other words, wastage of materials should be minimized during fabrication.
4. Cut the metal sheet according to the dimension specified in the layout using a tin snip. For thicker materials, use bench snip cutter to facilitate cutting of the metal sheet. Bend and cut bars as specified in the drawing. Note that cutting time during the production of the stove must be kept as short as possible. Based on our experience, six units of the stove can be finished in a small shop by two workers within one week.
5. Roll metal sheets with a pipe bender in forming the inner and the outer cylinders of the reactor, as well as the cylindrical parts of the burner assembly. When forming metal sheets, be careful not to abruptly bend the sheets so that the rolled cylinder would be uniform. You will fully gain confidence in making cylinders using these two pipes as more sheets are rolled into cylinders.
6. Fold metal sheet in making the char chamber. This can be done by placing the sheet on a straight angular bar and then hammering it on the straight edge of the bar to fold. In order to make accurate folding of the sheet, a bar folding machine can be used. Cutting Metal Sheet with Bench Snip. Forming Cylinders on Pipe Bender. Hammering the sheet for bending is the simplest way of folding metal sheet, however, finished product does not look attractive.
7. Weld all parts that need to be joined together. Oxyacetylene welding machine is advisable for welding thinner metal sheets, particularly in forming the inner reactor and the burner assembly where proper sealing is required. The outer reactor, char chamber, pot holder, support legs, char frame, and grate lever can be welded using the arc welding machine. After all the different parts are properly welded and constructed to the desired form, the surface of the welded parts should be smoothened using a power sander. See to it that the surfaces and edges are evenly smoothened before applying paint on them.
8. Fill the reactor with insulation using glass wool.
9. Apply paint on the stove to protect its surface and to make the unit more attractive. Spraying is the best way of applying paint on the stove. Using a roller brush is another way of applying paint on the stove. Note that applying paint using spray is not advisable to do when it is raining.
10. Install the fan and the electrical switches and check whether or not they are functioning properly. Make sure that the fan is properly bolted to the housing assembly. It should be carefully fixed into the housing without damaging the impeller so that it will minimize power loss during operation. The switch for the fan must be connected in series with the wire.

III. RESULTS AND DISCUSSION (PERFORMANCE TESTING AND EVALUATING)

The results of Rice Husk as a Fuel.

1. Start-Up Time =3.40 minutes
2. Operating Time =42.25 minutes
3. Total operating Time = Start-Up Time + Operating Time

= 3.40+ 42.25
= 45.65 minutes

4. Fuel Consumption Rate (FCR)
FCR= Weight of Rice husk fuel used/ Operating Time (hr).
FCR= 1(kg)/ 0.76(hr)
FCR= 1.32kg/hr

5. Specific Gasification Rate (SGR)
SGR= Weight of Rice husk Fuel used (kg)/ Reactor area (m^2)x Operating Time (hr)
SGR=1(kg)/{ $\pi/4\ (0.15)^2$x 0.76}
=74.45 kg/hr-m^2

6. Combustion Zone Rate (CZR)
CZR= Length of the Reactor (m)/Operating Time(hr)
CZR= 0.6/0.76
CZR= 78.94 m/hr.

7. Boiling Time= 14 minutes to boil 2 liter of water.

8. Sensible Heat
SH= Mw X Cp X (Tf-Ti)
SH= 0.96 X4.2 X (96-27)
SH= 278.20 KJ

9. Latent Heat
LH= We X Hfg
LH= 0.71X 2268
LH=1610 KJ

10. Heat Energy Input- This is the amount of heat energy available in the fuel. This is computed using the formula, QF= WFU x HVF
= 1x12600 KJ

11. Thermal Efficiency
TE= {[HS+LH]/[HF xWF]}x100
TE= {[278.20+1610]/[12600x1]}x100
TE= 15.0%

12. Power Input
Pi= FCR x HVF
Pi= 1.32 x 12600
Pi= 4.62 KW

13. Power Output
Po= FCR x HVF x TE
=1.32x12600x0.15
= 0.70 KW

3.1 Performance Test Results of the Stove

Test Results of tome taken

Loading Capacity	Weight of Fuel (kg)	Fuel Start-Up Time(min)	Gas Ignition Time(sec)	Total Operating Time(min)
Full Load	1.0	3.0	40	45.65

3.2 Test Results of Power Output and Efficiency of the Stove.

Loading Capacity	Fuel Consumption Rate (kg/hr)	Combustion Zone Rate (m/hr)	Specific Gasification Rate (kg/hr-m^2)	Power Input KW	Power Output KW	Thermal Efficiency (%)
Full Load	1.32	78.94	74.45	4.62	0.70	15

3.3 Test Results of Boiling Water using the Stove.

Volume of water in liter	Initial Temperature (°C)	Final Temperature (°C)	Boiling Time(min)
1	27	96	8
2	27	96	14

CONCLUSIONS

It is a good replacement for LPG stove, particularly in terms of fuel savings and quality of flame (i.e., luminous blue flame) produced during cooking. By direct energy conversion, about 23 tanks of 11-kg LPG fuel can be replaced by a ton of rice husks. It will significantly reduce the cost of household spending on conventional fuel sources such as electricity, kerosene, wood, and wood charcoal. It will help minimize the problem on husk disposal which contributes a lot on environmental pollution, especially the burning of this waste on roadsides and the dumping of the same along river banks. In this single burner husk gas stove, one kilogram of husk fuel per load per cooking will be used. For a typical Filipino family, about 1.095 tons of husks will be consumed per year in using this gas stove. In the Western Visayas region alone, if 25% of the entire household of 1,211,734 families (See Appendix 5) will use husk gas stove, 32,933.5 metric tons of husks are estimated to be consumed in a year. It will help reduce the carbon dioxide emission in the air brought about by the excessive burning of wood and other biomass fuel in the traditional cook stoves, which contributes to the ozone layer depletion and consequently in the “greenhouse effect” into the atmosphere. It will help preserve the forest by reducing the cutting of trees for the production of wood fuel and wood charcoal thus, minimizing problems concerning drought during summer and flood during rainy season. For every ton of husks utilized for cooking, about 847.45 kg of wood and 510.20 kg of wood charcoal can be preserved. It will provide employment and income generating projects for Filipinos in the production and marketing of the stove, and even in the selling of rice husk fuel in the future.

ACKNOWLEDGMENTS

This research was supported/partially supported by KLE Society. We thank our colleagues from K.L.E’S KLECET Chikodi, who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions of this paper.

We would also like to show our gratitude to the Dr. Sidramappa V.Itti, Principal K.L.E's KLE College of Engineering and TECHNOLOGY Chikodi, and Dr. Prasad B. Rampure HOD, for sharing their pearls of wisdom with us during the course of this research, and we thank 3 "anonymous" reviewers for their so-called insights.

We are also immensely grateful to 1] Dr. Siddesh 2] Mr. Pramod Alappanavar 3] Mr. Shivaraj Dalawai Staff Members of K.L.E's KLE College of Engineering and TECHNOLOGY Chikodi, for their comments on an earlier version of the manuscript, although any errors are our own and should not tarnish the reputations of these esteemed persons.

REFERENCES

[1]. G.D.Rai, "Non Conventional Energy Resources", Khanna publishers.2003

[2]. Kaupp A, and Gross J R, " Small Scale Gas Producer- Engine Systems", Federal Republic of Germany, A GATE Publicatio. P-29

[3]. Reed B T and Jantzen D, "GENGAS", SERI Press, 1982.

[4]. 'Design Principles for Wood Burning Cook Stoves'- by Dr. Mark Bryden, Dean Still, Peter Scott, Geoff Hoffa, Damon Ogle, Rob Baillis and Ken Goyer.

[5]. Mukunda H.S., Shrinivasa.U., and Dasappa. S (1988) " Portable Single Pan wood stoves of high efficiency".

[6]. Mukunda H.S., Shrinivasa.U., and Dasappa. S (1993) " Studies on stove for powdery biomass".

[7]. Reed, T.B., and Larson, R., A wood-gas stove foe developing countries, pp 985-993,

[8]. Developments in thermo chemical conversion, Blackies and professional, 1997.

[9]. Kohli .S, Ph.D. Thesis, Indian Institute of Science, Bangalore, 1992. "Buoyancy- induced flow and Heat transfer in Bio mass stoves".

★★★