IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. II (Mar. - Apr. 2016), PP 26-28
www.iosrjournals.org

Design And Fabrication Of Downdraft Gasifier Applied To I.C. Engine

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Abstract: *Today's Energy Hungry World is consuming non-renewable sources of energy such as fossil fuels at alarming rates, which has increased the importance of developing renewable energy sources. Biomass is one such source of renewable energy which is abundantly available in India in the form of industrial and agricultural by-products. In this project we aim to contribute in a small way to this changing face of sustainable energy resources by designing and fabricating a downdraft gasifier using two sources of biomass viz. rice husk and wood pellets. The syn-gas subsequently produced would be used to run an I.C. Engine and a performance analysis would be conducted.*

I. Introduction

Biomass gasification is basically the conversion of solid biofuels into a combustible gas mixture known as 'syn-gas' or 'producer gas.' A gasifier is a chemical reactor that performs this conversion

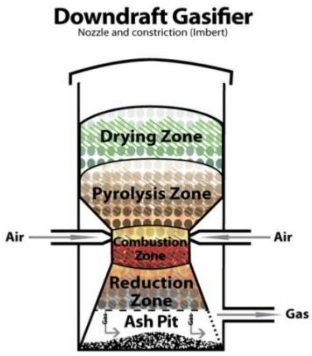


Fig.1. Working Principle of an Imbert type Downdraft Gasifier

Biomass resources are potentially the world's largest and most sustainable energy sources for power generation in the 21st century. The current availability of biomass in India is estimated about 500 million metric tonnes per year. Ministry of New and Renewable Energy has estimated surplus biomass availability at about 120 – 150 million metric tonnes per annum covering agricultural and forestry residues corresponding to a potential of about 17,000 MW.

Gasification is a thermo-chemical process by which carbonaceous (hydrocarbon) materials (coal, petroleum coke, biomass, etc.) can be converted to a synthesis gas (syngas) or producer gas by means of partial oxidation with air, oxygen, and/or steam. The device which performs this work is known as gasifier. Gasifier is a chemical reactor where various complex chemical and physical processes take place. A hydrocarbon feedstock (biomass) is fed into a high-pressure, high-temperature chemical reactor (gasifier) containing steam and a limited amount of oxygen. As biomass flows through the reactor it gets dried, heated, pyrolysed, partially oxidized and reduced. Under these "reducing" conditions, the chemical bonds in the feedstock are severed by the extreme heat and pressure and producer gas is formed. The main constituents of producer gas are hydrogen (H_2) and carbon monoxide (CO). A typical composition of syngas produced from wood gasification on volumetric basis is given below, Producer gas derived from biomass can be used in IC engine with some modifications. Spark ignition (SI) engine can be made to run entirely on producer gas and compression ignition (CI) engine replaces 60% - 80% fuel oil by using producer gas.

Compound	Symbol	Gas (Vol. %)	Dry gas (Vol. %)
Carbon monoxide	CO	21	22.1
Hydrogen	H_2	14.5	15.2
Methane	CH_4	1.6	1.7
Heavier hydrocarbon	HC	0.3	0.4
Carbon dioxide	CO_2	9.7	10.2
Nitrogen	N_2	48.4	50.8
Water vapour	H_2O	4.8	-

II. Experimental Details

2.1. Design Procedure

The first step was to select an engine. Considering the budget of our project we select an genset having an output of 4KW. The next steps involved some calculations of stroke volume and gas output that the gasifier would have to produce considering an air gas ratio of 1.1:1.

The crucial part involved the selection of the Hearth Load. An important factor in the sizing of any gasifier is the superficial velocity of the gas when it passes through the narrowest part of the gasification zone. It actually represents the specific gas production rate i.e. gas volume per unit cross sectional area per unit time. A closely related term is the maximum hearth load which is expressed as gas volume/hearth area-hour. This term enables one to compare the performance of a wide range of gasifiers on a common basis.

For an Imbert Downdraft Gasifier the maximum Hearth Load is 0.9 m^3/cm^2-h, which is has been determined by experimental tests. Using this term, we calculated the throat diameter. Subsequently a standard set of dimensions was chosen from the following standard table from the SERI Handbook.

Table 5-2. Imbert Nozzle and Hearth Diameters

d_r/d_h	d_h mm	d_r mm	$d_{r'}$ mm	h mm	H mm	R mm	A No.	d_m mm	$\frac{A_m \times 100}{A_h}$	$\frac{d_r}{d_h}$	$\frac{h}{d_h}$	Range of Gas Output max. Nm^3/h	Range of Gas Output min. Nm^3/h	Maximum Wood Consumption kg/h	Air Blast Velocity Vm m/s
268/60	60	268	150	80	256	100	5	7.5	7.8	4.5	1.33	30	4	14	22.4
268/80	80	268	176	95	256	100	5	9.0	6.4	3.3	1.19	44	5	21	23.0
268/100	100	268	202	100	256	100	5	10.5	5.5	2.7	1.00	63	8	30	24.2
268/120	120	268	216	110	256	100	5	12.0	5.0	2.2	0.92	90	12	42	26.0
300/100	100	300	208	100	275	115	5	10.5	5.5	3.0	1.00	77	10	36	29.4
300/115	115	300	228	105	275	115	5	11.5	5.0	2.6	0.92	95	12	45	30.3
300/130	130	300	248	110	275	115	5	12.5	4.6	2.3	0.85	115	15	55	31.5
300/150	150	300	258	120	275	115	5	14.0	4.4	2.0	0.80	140	18	67	30.0
400/130	130	400	258	110	370	155	7	10.5	4.6	3.1	0.85	120	17	57	32.6
400/150	135	400	258	120	370	155	7	12.0	4.5	2.7	0.80	150	21	71	32.6
400/175	175	400	308	130	370	155	7	13.5	4.2	2.3	0.74	190	26	90	31.4
400/200	200	400	318	145	370	153	7	16.0	3.9	2.0	0.73	230	33	110	31.2

Variables not given in figure are defined as follows:

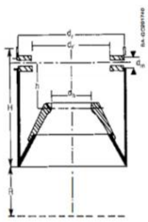
d_m = inner diameter of the tuyere.

A_m = sum of cross sectional areas of the air jet openings in the tuyeres.

A_h = cross sectional area of the throat.

A = number of tuyeres.

Source: Kaupp 1984a, Table 5; Fig. 75.

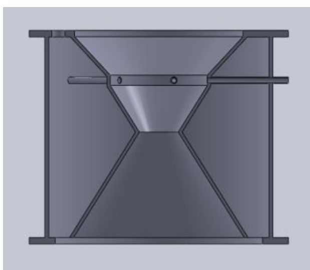


Gasifier Des

Subsequently, the biomass consumption rate was calculated with certain assumptions.

2.1. Final Design

The initial design was presented to the fabricator. He suggested certain improvements in the design which were implemented and the gasifier was redesigned. A sectional view of the design of the throat section is shown below.



The other components include a hopper section, ash section and flanges.

2.3. Material Procurement and Fabrication

Once the design was finalised, we had to determine the amount of material that would be required for the various components. Stainless steel was chosen as it can sustain the high temperatures of up to 1200^{o}C which would be attained at the throat section. Initially we procured suitable scrap materials in order to reduce the cost and the remaining materials where ordered from a vendor. Once all the required materials were procured the fabrication was started. It took approximately 2 weeks for the fabrication to complete. The only problem faced was in procurement of pipes, as pipes of the required diameter were not available, they had to be machined on a lathe machine. The wood pellets having moisture content less than 14% were then subsequently procured.

2.4. Experimentation and Analysis

Once the complete assembly of the gasifier is finished, it would be operated using wood pellets as biomass and charcoal grate for initial starting. The gas generated would be tested to determine its composition, calorific value and most importantly tar content. A photograph of the fabricated gasifier is shown below.

III. Results And Discussion

From the above description, we can conclude that such a downdraft gasifier will be applicable to many small scale industries. Especially the industries which produce large quantities of biomass byproducts would largely benenift from the implementation of such a gasifier based system, which would see a drastic fall in the fuel requirements and in turn would increase profits.

An added advantage of downdraft gasifiers over other types is that the gas produced has minimal tar content which enables the gas to be used in a I.C. Engine with minimal or no prior conditioning.

IV. Conclusions

1. Drastic reduction in fuel consumption.
2. Low Tar content.
3. Easily implemented in small scale industries, which would cause saving of non-renewable energy resources and provide an alternate sustainable energy source.

Acknowledgments

The team members pay sincere gratitude to Prof. Dipak Choudhari, Head of Department, Civil Engineering V.C.E.T, Vasai for guiding us on the topic and encouraging us to participate in the paper presentation event. We thank him for sharing his vital inputs on the topic and developing an interest to learn and understand new technologies introduced in the field we are studying.

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