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DESIGN AND DEVELOPMENT OF DOWN DRAFT WOOD GASIFIER

S. SIVAKUMAR[1], N. RANJITHKUMAR[2] & S. RAGUNATHAN[3]

[1]Assistant Professor, Department of Production Engineering, JIT, Thoppur, Tamil Nadu, India

[2]Department of Mechanical Engineering, JIT, Thoppur, Tamil Nadu, India

[3]Professor, Department of Production Engineering, JIT, Thoppur, Tamil Nadu, India

ABSTRACT

The gasification technology is now considered to be in an advanced stage of development. Hence there is huge expectation from the user industry for its application. It is well known that wood can be used to operate internal combustion engine to produce mechanical power. For wood as gasifier which is capable of producing tar free gas has to be used or the tar has to be reduced to an acceptable level before it can be used to avoid the possibility of contaminating the engine. The aim of this paper is focused on a 10 kW down draft wood gasifier system is designed using empirical data and derived quantities

KEYWORDS: Down Draft Gasifier, Wood, and Gasification

INTRODUCTION

Thermo chemical conversion of woody biomass under restricted supply of oxidant is among the most promising non-nuclear forms of future energy. Besides utilizing a renewable energy sources, the technology also offers an eco-efficient and self sustainable way of obtaining gaseous fuel usually called producer gas. It can be used in either premixed burners (dryers, kilns, furnaces or boilers) for thermal applications or in direct feeding of high efficiency internal combustion engines/gas turbines for mechanical applications. After adequate cleaning up and reforming, the generated gas can also be used for feed high temperature fuel cells or for production of hydrogen fuel [1].

For electric power generation applications, the motive power from prime mover such as IC engine or gas turbine can be connected to an electric generator to produce electric energy. Applications of IC engines have proved to be the most efficient and least expensive decentralized-power-generation systems at lower power range. Research efforts have been expanded worldwide to develop this technology cost-effective and efficient in lower power range.

The gasification reactions are mainly endothermic and thus, heat has to be supplied to the reactor. In directly heated gasifiers, the heat necessary for the endothermic reactions is provided by combustion or partial combustion of the biomass within the gasifier (auto thermal gasification). In indirectly heated gasifiers, the heat is generated outside the gasifier and then exchanged with the gasifier by means of a heat exchanger or a heat carrier. Auto thermal gasification reactors mostly use air as gasification medium because pure oxygen is economic feasible only in large-scale installations [2]. Gasifiers can operate at low (near atmospheric) or high (several atmospheres) pressure.

Temperature and pressure operating conditions as well as residence time are key factors in determining the nature and 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.

Downdraft gasifiers try to avoid the disadvantage of high tar contents by injecting the gasification agent not at the bottom but to a certain height above the bottom. The main difference to updraft gasifiers is that the gas flows co currently downwards with the biomass. This leads to a different order of the reaction zones from top to bottom, namely, drying, pyrolysis, oxidation, and reduction zone with the result of a low tar content in the fuel gas. The main disadvantage of this kind of gasifier configuration is the high carbon content in the bottom ash. This can be explained by the reduction zone, which is the first zone above the grate [3]. Another gasifier option is the twin-fire fixed bed gasifier, which is able to combine the advantages in one gasifier and avoid the disadvantage of both systems above.

The downdraft gasifiers can be 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 -21.3% [4, 5]) create, problems by ash clogging and slogging at the combustion zone in downdraft gasifiers. The choke plates and throat type combustion regions used in downdraft gasifiers work well with lower coking tendency fuels (e.g. wood), but when high coking fuels (e.g. cotton stalk) are used they cause bridging in and above the pyrolysis zone [6, 7].

The main advantages of fixed bed gasifier configuration can be summarized as follows: Simple and reliable design; Capacity for wet biomass gasification and favorable economics on the small scale. However, the main technical challenges that have to be faced include: Long residence time; Non-uniform temperature distribution; Possible high char or/and tar contents in the fuel gas and low productivity [8].The main design criteria considered for well functioning gasifier are[9]:

- High heating value of the gas, meaning high content of H_2 and $C0_2$ -5000 kJ/Nm^3 seems quite good with 10 - 30 % moisture in feedstock.
- Low content of tar, commonly a value of 0.5 g.Nm-^{3} dry gas is given, but values of 0.2 are preferable.
- Thorough burn-out of the carbon (>95%), which implies a high efficiency of the process. (70-75% should be attainable)
- Unhampered down flow of the feed.
- Low Pressure Drop

We have tried now to establish from the available data in the old literature the parameters and their values necessary for design of a down draft wood gasifier of a 10 kW capacity.

Theory of Gasification

Woodchips move downward and get converted to useful gas (and ash) as shown in the figure 1.Heat transmitted from the combustion zone chars the wood chips as they approach the air inlet. In the process, they lose most of their moisture content and some volatilcs, which is known as pyrolysis and takes place at the bottom of the hopper zone P(figure 1)) where the temperature is about 200°C or more. The partially charred wood and the gases meet the oxygen from the air near the inlet nozzles and combust fiercely.The typical temperature during combustion is about 1200°C and the pieces of charred wood get reduced in size as they move downward to the reduction zone. The gases produced in the combustion zone are typically CO_2, and H_20. As they proceed further, these gases along with N_2, from the incoming air meet a hot zone of charcoal. There CO_2, gets reduced to CO with H_2O participating in two reactions as shown below:

The Boudouard reaction:

$$C + CO_2 \rightarrow 2CO$$

The water gas reactions :

$$C+H_20 \rightarrow CO+H_2$$

$$CO_2+ H_2 \rightarrow CO + H_2O.$$

An examination of the equilibrium relations between the various species participating in the reactions suggests that the conversion of CO_2, to CO is nearly complete beyond 1000°C but falls steeply to 30% at 600°C.

A typical composition of wood gas is CO (20-25 %), H_2 (16-18 %), CO2 (8-10%)) and N_2, (45-50 %) with traces of other combustible gases like methane and higher hydrocarbons. Its heating value is 1100-1250 kcal/kg. This would mean that to produce shaft power output equivalent to that of 1 litre of gasoline,3kg of wood (or 1-7 kg of charcoal) is required in practical operations In the down-draft (co-current) type the fuel and the gases move in the same direction inside t h e hearth. It has a constriction in the passage (below the air inlets) through which all the hot gases have to pass. The tar and the other volatiles produced during pyrolysis get cracked significantly in this zone, thereby delivering a relatively clean gas when the hearth parameters are optimized.

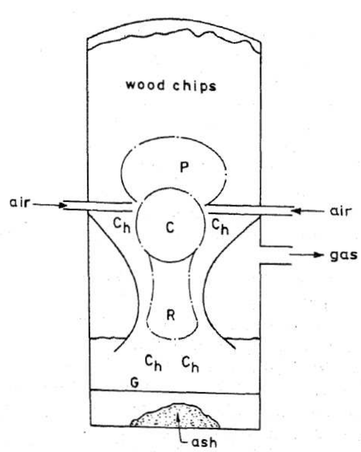
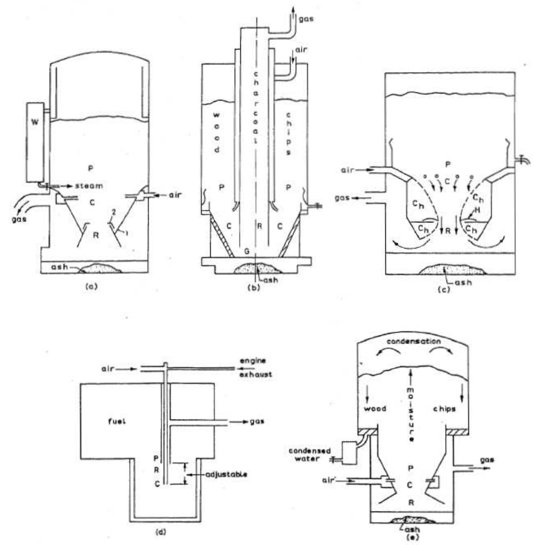


Figure 1. Typical gas generator. C_h: char; G: grate; P, pyrolysis; C, combustion; R, reduction.



Figures 2: A to 2d Show Four of the Several Designs Which Went into Commercial Roduction. These Are the Imbert Design, the Brandt Design, the Kalle Design and the Zeuch Design, the Figures Are Self-Explanatory in Showing the Various Zones, Namely, Combustion, and Reduction

DESIGN OF DOWN DRAFT GASIFIER

Design of gasifier essentially means obtaining the dimensions of the various components of it. Design of gasifier is largely empirical. Design of gasifier is carried out partly through computations and partly using empirical relations and using some experimental data. The principal design parameters are specific gasification rate (SGR), gas resistance time (GRT) and area of air nozzles. The derived parameters are diameter of hearth and throat , total length of combustion and reduction zone, air velocity, diameter of nozzles and number of nozzles etc.

Design Rating

The present design is meant for supplying enough wood gas to drive a 10 kW engine Since it is reasonably well known that the amount of diesel that can be replaced is about 70-80 %, the amount of power for which the gas generator is to be designed is about 8 kW.

Hearth Load (GH)

The design of an Imbert type downdraft gasifier is based on specific gasification rate, also called the hearth load GH. It is defined as the amount of producer gas to be obtained per unit cross-sectional area of the throat, which is the smallest area of cross-section in the reactor. It is normally expressed in terms of $Nm^3/h\ cm^2$, where N indicates that the gas volume is calculated at normal pressure and temperature conditions. It is reported that the gasifier can be operated with GH in the range 0.1–0.9 $Nm^3/h\ cm^2$. Normal Imbert gasifiers show a minimum value of GH in the range 0.30–0.35, resulting in a power turndown ratio of about 2.5–3.[11]

The hearth load varies between an upper limit, GHmax,above which the gas quality is poor because of charcoal dusting in the combustion zone and a lower limit, GH min below which due to too low a temperature in the hearth, the gas will contain unacceptably large quantities of tar.In Impart wood gas generators and other similar reactors, GH max reaches about 0.9 in continuous operation and GH min about 0.3 t o 0.35. For the design here, GH max as been assumed to be 0.9 and the rated power of 3.5 hp is assumed to be obtainable at a GH rated of 0.8 $Nm^3/h\ cm^2$ [12,13]

Specfic Fuel Consumption

This is computed from the formula:

Specific fuel consumption,

(SFC) (kg/hp- hr) = 632/ηen* ηmot*cvw [14]

ηen - 0.70 (this value corresponds to the case where the gas coming out of the generator has to be cooled to room temperature and where no provision has been made for heat recovery),

ηmot = 0.22

cv_w =3500kcal/kg(for wood with 20 % moisture)

Specific fuel consumption,(SFC) = 1.17 kg/hp-hr

Fuel Consumption

Since it has been assumed that 10.8 hp will be delivered at Bhrated Bh = 0.8 $Nm^3/h\ cm^2$, the power that can be delivered at Bhmax is 4 hp. Therefore, nominal fuel consumption (at3.5 hp) = 4 kg/hr and maximum fuel consumption (at 10.8 hp) = 12.8 kg/hr.

Throat Diameter (DT)

This is obtained from the maximum fuel consumption and GHmax From SERI Report (1979) the quantity of gas generated is about 2.2 Nm^3 for every kg of wood with 20 % Moisture content. Therefore, the

Maximum gas generation = 11.5 Nm^3/hr.

Hence the throat area = 11.46 cm^2

Throat diameter = 6.3 4 cm.= 63mm

Sivakumar et al. [15] discovered from their model that for throat angles of about 45˚, the cumulative conversion efficiency is increased while larger angles of about 90˚ decrease the cumulative conversion effeciency because of a decreased temperature for larger throat angles due to the divergent effect and the reaction rate. Venselaar [19] also recommended, after comparison of the design characteristics of a number of gasifiers, that the throat inclination should be around 45˚ to 60˚. A throat angle of 60˚ is used .

Design of Hearth or Fire Box (D_H) & Nozzle

Height of the nozzle (h/dt)	84	mm
Nozzle ring Diameter	150	mm
Number of nozzle	6	
Diameter of nozzle	8	mm
Hearth Diameter	310	mm

Diameter of the fire box or hearth,Other dimensions such as the diameter of nozzle top ring, height h of the nozzle plane above the throat, nozzle area are calculated from the graph given by the Swedish Academy of Engineering Sciences

Superficial Velocity of Air

The “superficial velocity” (hearth load) of a gasifier is the most important measure of its performance, controlling gas production rate, gas energy content, fuel consumption rate,power output, and char and tar production rate.

The superficial velocity, SV, of a gasifier is defined as:

SV = Gas Production Rate/Cross Sectional Area

$= (m^3/s)/(m^2/s) = m/s$

It is easily estimated or measured by measuring gas production rate or fuel throughput and gasifier dimensions. It controls the rate at which air, then gas, passes down through a gasifier. This in turn exercises a primary effect on heat transfer around each particle during flaming pyrolysis of the volatiles, combustion of the tars and gasification of the charcoal.

Here the controlling parameters are air inlet velocity and number of nozzles. High velocities will produce narrow jets and Low velocities will not reach the central area. Both cases lead to formation of central dark zone meaning poor non-uniform combustion zone and inefficient tar cracking.

- General range for air inlet velocity is 6 m/s to 10 m/s [18]
- Number of nozzles to be used – generally ranges from 1 to 10.
- The aim of the nozzle design is to have no cold/dark zones in the oxidation zone.
- Selection of 6 nozzles seems suitable. In general 4 * 57, 5 * 52, 6 * 47 are recommended and for the present case 6 * 47 have been selected[18].

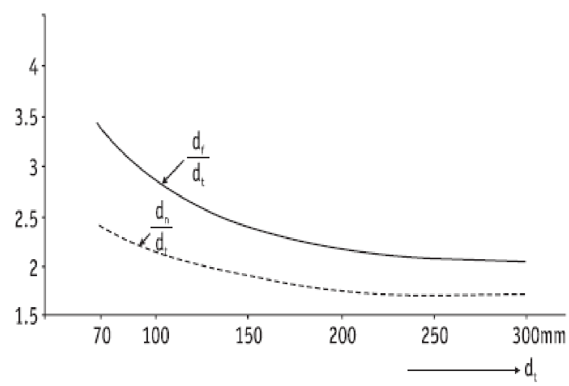


Figure 4: Nozzle Ring Diameter as a Function of Throat Diameter

Source FAO (1986)

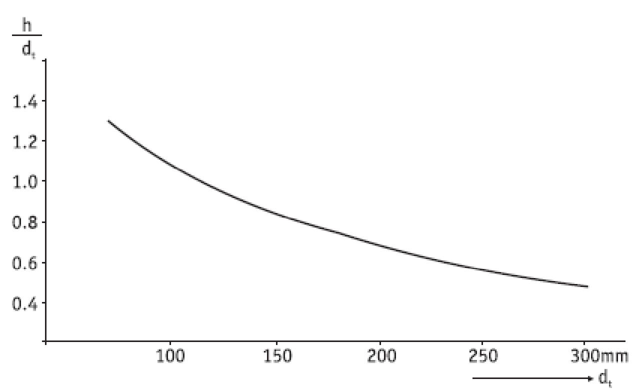


Figure 5: Height of Nozzle Plane above Throat for Various Throat Diameters

Source FAO (1986)

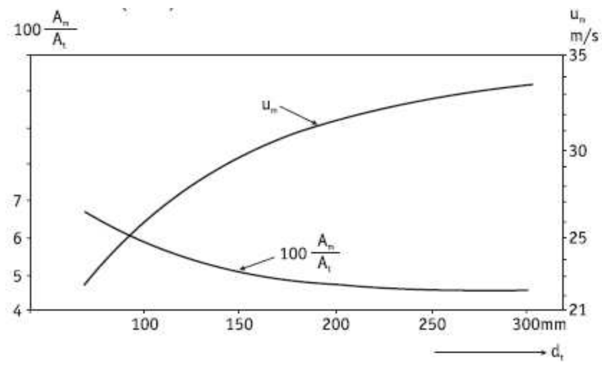
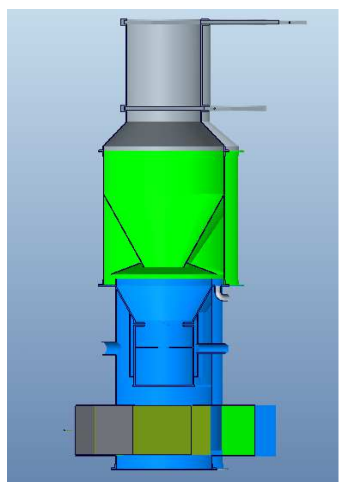


Figure 6: Nozzle Area for Various Sizes of Gasifier Throat

Source FAO (1986)

Equivalence Ratio (ER)

ER is defined as the ratio of oxygen supplied per kg wood to the stoichiometric requirement. ER fixes the amount of air supplied for gasification. A value of 0.3 ER is the theoretical optimum [19]. As the ER value approaches 1.0 combustion reaction is predominant and as it tends to zero, pyrolysis is the major process. All the gasifier designs were based on the above mentioned optimum. For a given biomass consumption rate, the volumetric rate of air can be calculated from ER value [20].



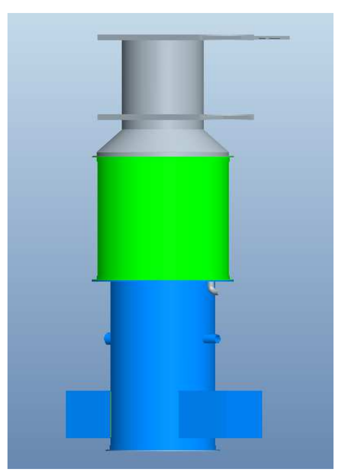


Figure 7: Design of Downdraft Wood Gasifier

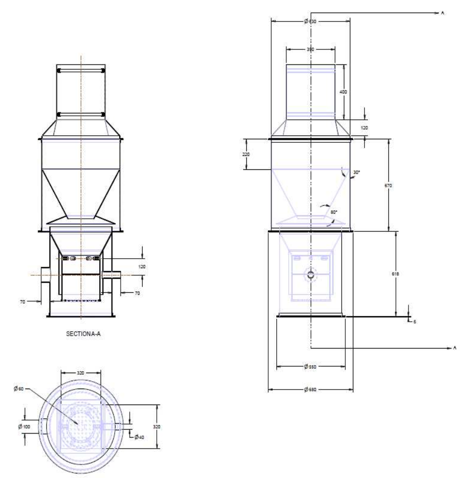


Figure 8: Schematic Design of Downdraft Wood Gasifier

Fig.7 and Fig 8. Shows the schematic design of the down draft gasifier. That is the diagram is drawn as a block diagram and its material thickness is not shown. Firing nozzle is used start the combustion process. Ash and gases will pass through the grate region . Ash will be collected in the ash pit and producer gas will leave the gasifier through the gas outlet connection weights of links between neurons, and information are processed in parallel.

CONCLUSIONS

A small scale downdraft wood gasifier was designed to deliver a mechanical power of 10 kW for running diesel engine. The key features of the downdraft gasifier , namely, the hearth diameter, the air entry zone and the construction of the reduction zone have been identified and the non-optimal performance due to the wrong choice of these parameters has been brought out.The small scale Wood biomass gasifier has a capacity of holding 12.8 kg/hr of wood . The hearth and throat diameter are 310 mm and 638 mm respectively. It had 6 nozzles, 8 mm diameter, for the injection of air.

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