OXYGEN-BLOWN GASIFICATION OF BIOMASS TO PRODUCE CLEAN SYNTHESIS GAS FOR USE IN ENGINES

A Report Submitted to

Puducherry Council for Science and Technology,
Department of Science, Technology and Environment,
Government of Puducherry

by

Dr. L. Kumararaja
Associate Professor

Department of Mechanical Engineering
PONDICHERRY ENGINEERING COLLEGE
(Sponsored by Govt. of Puducherry and affiliated to Pondicherry University)
Puducherry – 605 014.

Ph. Nos: 0413-2655281-287 Website: www.pec.edu
Fax No : 0413-2655101

OXYGEN-BLOWN GASIFICATION OF BIOMASS TO PRODUCE CLEAN SYNTHESIS GAS FOR USE IN ENGINES

ACKNOWLEDGEMENTS

The project titled "Oxygen-blown gasification of biomass to produce clean synthesis gas for use in engines" has analyzed the use of oxygen as gasification medium for conversion of wood to synthesis gas.

At the outset, I thank **Dr. K. Mahadevan**, Professor and Head, Department of Mechanical Engineering, Pondicherry Engineering College, for his support in the execution of the project and also for allowing me to use the facilities available in the department.

I am grateful to **Dr. P. Dananjayan**, Principal, Pondicherry Engineering College, for his help in the procurement of equipments pertaining to the project. I gratefully acknowledge the guidance of **Dr. K. Subbarayudu**, Professor, Department of Mechanical Engineering, Pondicherry Engineering College, and the support of **Mr. S. Kader** and **Mr. G. Nexon Brissac**, II year M.Tech (Energy Technology) students who did their project works related to this developmental project. It is my duty to thank all those who are in one way or other helped me in the execution of the project.

This project was executed with the financial grant of Rs.55,000/- received from Puducherry Council for Science and Technology, Department of Science, Technology & Environment, Government of Puducherry. I express my deep gratitude to **Dr. M. Dwarakanath,** Member Secretary, Puducherry Council for Science and Technology, for funding this project.

L. KUMARARAJA

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The energy generation technologies from renewable sources have gained importance due to their sustainability and environmental friendliness. Biomass being one of the renewable sources of energy can be utilized to derive energy through various means. One such method is ‘biomass gasification’ which makes possible the conversion of solid biomass to a gaseous fuel. In this project, one of the gasification techniques known as ‘oxygen-blown gasification’ is used for the generation of gaseous fuel from wood pieces. The gaseous fuel is called synthesis gas or syn gas and it has a heating value of about 9000-10000 kJ/m^3.

The oxygen-blown gasification technique involves the admission of industrial oxygen in sub-stoichiometric quantity to a chemical reactor called biomass gasifier for the conversion of wood pieces to syn gas. The auto-thermal gasification of wood pieces takes place within the gasifier producing syn gas. Instead of supplying oxygen to the gasifier, if air is supplied, then producer gas only can be generated whose heating value is a meager 4000-4500 kJ/m^3.

Before constructing the experimental set up, an extensive literature review was carried out to know the intricacies involved in the oxygen-blown gasification. An oxygen-blown gasifier operating at atmospheric pressure has been fabricated. It has a maximum thermal power rating of 16 kW. Some of the features of the gasifier are: (i) regulated supply of biomass, (ii) accurate metering of the oxygen flow rate, (iii) flash back arrestor in the oxygen supply line, (iv) less surface heat loss from the gasifier, and (v) swirl burner for the syn gas. The experimental set up has been fabricated and tested for its performance. The results of oxygen-blown gasification have also been compared with those of air-blown gasification of wood pieces. The results indicate that oxygen-blown gasification of wood pieces can generate a good quality syn gas. When burnt, the syn gas produced a stable flame in the burner.

If it is required to drive an engine, then instead of burning it in a burner, the syn gas must be thoroughly cleaned to remove the tar and particulate matter before supplying to the engine. It is the cost of industrial oxygen which finally decides the applicability of syn gas for engines.

Chapter1

INTRODUCTION

1.1. Theory

Biomass gasification is one of the promising renewable energy technologies. In this method, biomass is converted to a gaseous fuel called producer gas by the thermo-chemical reaction with sub-stoichiometric air. It has a heating value of 4000 - 4500 kJ/m^3 and has got several applications like (i) mechanical power generation by means of prime movers such as internal combustion engines, gas turbines, (ii) process heating in furnaces, kilns, (iii) synthesis of manufactured fuels like methanol, etc. The lower heating values of some gaseous fuels are given in Table 1.1.

Table 1.1 Lower Heating Values of some gaseous fuels

Sl. No.	Name of fuel	Range of lower heating value (kJ/Nm^3)
1	Blast furnace gas	3000-3200
2	Producer gas	4000 - 4500
3	Synthesis gas or syn gas	9000-10000
4	Bio gas	17000 - 25000
5	Natural gas	32000 - 34000
6	Liquefied Petroleum Gas	100000 - 110000

In the Table 1.1, the heating value of every fuel gas is given as a range, since the volumetric composition of the fuel gas generally varies over a range. It can be observed that synthesis gas or syn gas has twice the heating value of producer gas.

1.2. Comparison between producer gas and syn gas

The syn gas has distinct properties when compared to producer gas. The present project was to develop a reactor for syn gas generation so that the gas can be supplied to an internal combustion engine. The comparison between producer gas and syn gas is given in Table 1.2.

Table 1.2 Comparison between producer gas and syn gas

Sl. No.	Producer gas	Syn gas
1	The typical composition of producer gas is: CO – 16 %, H_2 – 17 %, CH_4 – 1 %, CO_2 – 13 %, H_2O – 4 %, N_2 – 49 %	The typical composition of syn gas is: CO – 30 %, H_2 – 35 %, CH_4 – 10 %, CO_2 – 18 %, H_2O – 6 %, N_2 – 1 %.
2	The heating value of producer gas is 4000-4500 kJ/Nm^3.	The heating value of syn gas is 9000-10000 kJ/Nm^3.
3	Air is the gasifying medium during the generation of producer gas.	Oxygen is the gasifying medium during the generation of syn gas.
4	CO_2 removal is difficult due to its lower partial pressure in the mixture.	CO_2 removal is easier due to its higher partial pressure in the mixture.
5	The adiabatic flame temperature of producer gas combustion is lesser.	The adiabatic flame temperature of syn gas combustion is higher.
6	Size of the gasifier is bigger for a given thermal power rating.	Size of the gasifier is smaller for the same thermal power rating.
7	The range of inflammability limits is small.	The range of inflammability limits is large.

Chapter 2

LITERATURE REVIEW

The air-blown gasification has been researched well both theoretically and experimentally by many researchers. At present, air-blown gasification systems for engine applications are commercially available in the market. But research on oxygen-blown gasification is limited. Few journal papers on oxygen-blown gasification are reviewed as given below:

2.1. Reviews

2.1.1. M. Rivarolo and A. F. Massardo [1] have analyzed the integration of oxygen-blown biomass gasification with bio-methane generation. The optimization of an integrated system of 1 MWe water electrolyser, oxygen-blown gasifier, syn gas purifier and methanator has been done. The "spilled water electricity" is used for producing hydrogen and oxygen. The oxygen is then supplied to pressurized oxygen-blown biomass gasifier to generate syn gas. Using hydrogen from the electrolyzer and syn gas from the gasifier, bio methane is produced. It is considered thermo-economically attractive if spilled energy is available. The bio-methane production plant is also suitable from an environmental point of view.

2.1.2. Timothy C. Williams et al. [2] studied the combustion characteristics of syn gas in air and CO_2 diluted oxygen in a lab scale gas turbine combustor operating at 1 atm. It was believed that global climate change concern may dictate the generation of a CO_2 product stream for end-use or sequestration, with potential impacts on the oxidizer used in the gas turbine. This prompted them to test gas turbine combustors with unusual gaseous fuel mixtures. They have found that the presence of hydrogen in the syn gas fuel mixtures results in more compact, higher temperature flames, resulting in increased flame stability.

2.1.3. Jeffrey Phillips [3] has given an account of the gasifiers and their integration with gas turbines in a web document titled 'Different types of gasifiers and their integration with Gas Turbines'. He compared the advantages of oxygen-blown gasification with air-blown gasification. Air-blown gasifier avoids the large capital cost of an Air Separation Unit (ASU). But, it produces a much lower calorific value syn gas than oxygen-blown gasifier. The nitrogen in the air dilutes the syn gas by a factor of approximately 3 when compared to oxygen-blown gasification.

This has a significant impact on the design of the combustion system of gas turbine. If CO_2 capture is also required in the gas turbine power generation, then air-blown gasifiers have only a negative impact. Because of the dilution effect of the nitrogen, the partial pressure of CO_2 in air-blown gasifier syn gas will be one-third of that from oxygen-blown gasifier. This increases the cost and decreases the effectiveness of the CO_2 removal equipment. If CO_2 capture is also contemplated along with gas turbine power generation, then oxygen-blown gasification is recommended.

2.1.4. Combustion and NO_x emissions of biomass-derived syn gas under various gasification conditions utilizing oxygen enriched air and steam were analyzed by Cuong Van Huynh and Song-Charng Kong [4]. They operated the biomass gasifier with pine, maple-oak mixture and seed corn. The biomass derived syn gas was burned in an industrial burner that was integrated into the gasification system. NO_x emissions were measured and it was found that it was higher in the combustion of syn gas derived from biomass when compared to that of natural gas. However, for leaner mixtures the NO_x emission was minimum.

2.1.5. Amit C. Gujar et al. [5] conducted a series of tests on oxygen gasification of pine charcoal in a top-lit downdraft moving hearth gasifier. It was found that in the range of O_2 flow rates tested (1–5 g/min), higher flow rates of oxygen resulted in higher concentrations of H_2 and CO as well as higher charcoal gasification rates. Their experimental results underscored the importance of maintaining efficient heat transfer within the gasifier and reducing the heat losses to the surroundings.

2.1.6. Nazim Muradov et al. [6] operated a gasifier in a semi-continuous updraft mode using a steam-oxygen mixture (in the range of $[H_2O]/[O_2]$ = 2.2–4.4 mol/mol) as an input oxidizing gas. The effect of gasification parameters, including the rate of oxygen flow and steam/oxygen molar ratio on the syn gas yield and composition was determined. It was found that increasing oxygen flow rate into the gasifier (by a factor of 2.3) resulted in higher (by 32%) H_2/CO ratio. The syn gas from the gasifier was scrubbed of particulate matter and traces of oxygen and dried before it was directed to a Fischer-Tropsch synthesis reactor.

2.1.7. E. Simeone et al. [7] operated a steam and oxygen-blown gasifier fed with different types of biomass. The gasifier was a circulating fluidized bed type and the generated syn gas was cleaned in a high temperature ceramic candle filter. They tested the gasification and filtration for about 50 hours of operation. The filtration efficiency was as high as 100 %. It required a blow back pressure of about 300 kPa and pulsing frequency of 10–15 min.

2.1.8. Atmadeep Bhattacharya et al. [8] developed a thermodynamic model to evaluate the yield of hydrogen from biomass through gasification in an oxygen-rich environment followed by carbon monoxide shift reaction with the injection of water. The effects of operating conditions, like gasifier equivalence ratio, quantity of water injected in the shift reactor and oxygen percentage in the gasifying agent, on the hydrogen concentration in the product gas from biomass have been evaluated. It is predicted that the process can generate 102 g hydrogen per kg of biomass, resulting in a cold gas efficiency of 65.4%. However, the air separation unit consumes a considerable amount of work in compression and refrigeration.

On a large scale, many Integrated Gasification Combined Cycle (IGCC) power plants are in operation abroad for electric power generation. In India, BHEL undertakes the research on IGCC using oxygen-blown coal gasifier.

2.2. Setting the Objectives

After the literature review, certain inferences were drawn and on the basis of which the following objectives for the present work were formulated:

- To construct an oxygen-blown, co-current type biomass gasifier of 16 kW thermal power rating using firewood as fuel and oxygen as gasification agent to produce synthesis gas
- To incorporate the accessories like oxygen cylinder, pressure regulator, oxygen flow meter, flash back arrestor, burner, etc. in the gasification system
- To conduct experiments on the oxygen-blown gasifier in order to determine its performance characteristics vis-à-vis air-blown gasifier.

Chapter 3

CONSTRUCTION OF OXYGEN-BLOWN GASIFICATION SYSTEM

In the present research work, oxygen was used as the gasification agent instead of atmospheric air. The objective was to get a high heating value syn gas. The gasification process remained the same with the use of oxygen also. But, certain additional equipments were required to be provided in the oxygen supply line.

3.1. Components of oxygen-blown biomass gasification system

The schematic diagram of the oxygen-blown gasification system is shown in Figure 3.1. The air blower of a conventional gasification system is replaced by an oxygen supply line consisting of an oxygen cylinder, two-stage pressure regulator, oxygen flow meter, flash back arrestor. In this case, no air blower is necessary as oxygen is supplied at a higher pressure from the cylinder.

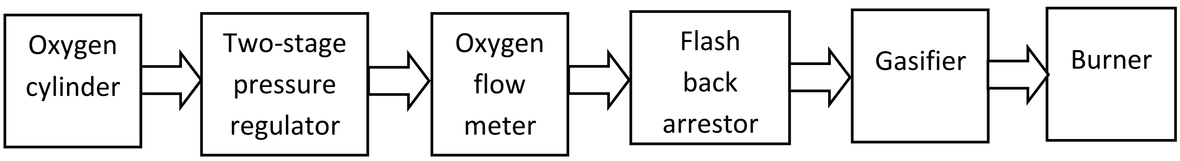

Figure 3.1. Schematic diagram of oxygen-blown biomass gasification system

In the case of small gasifier of a few kW of thermal power rating, oxygen obtained from a single cylinder is sufficient. If the thermal power rating of the gasifier is high, then oxygen obtained from a single cylinder may not last longer. In such a situation, oxygen can be obtained either from a bank of oxygen cylinders or from an air separation unit.

3.2. Oxygen cylinder

It is the cylindrical storage tank containing pressurized oxygen at about 150 bar. The volumetric capacity of the cylinder is about 50 litres. The oxygen required for gasification is supplied from this cylindrical storage tank. There is a precise relationship between cylinder pressure and mass of the oxygen that is contained in the cylinder. The photographic view of oxygen cylinder is shown in Figure 3.2.

Figure 3.2. Oxygen cylinder

Oxygen is manufactured in the industry by cryogenic air separation technology at a commercial scale and bottled in the oxygen cylinders. The power consumption for the production of oxygen by this technology is about 0.5 kWh/Nm^3 of oxygen.

3.3. Two-stage pressure regulator

A pressure regulator is a control valve that reduces the pressure of inlet fluid to a desired value at the outlet. It is provided at the outlet of the oxygen cylinder. It reduces the pressure of oxygen as it flows out from the oxygen cylinder to a value that is required in the gasifier. A pressure regulator which is the best in class for safety and performance has been selected for use in the experimental set up.

The pressure regulator is a two-stage type. It is more durable than single stage pressure regulator. The piston of the first stage and the diaphragm of the second stage create a constant delivery pressure. The gas emerges out at a working pressure set by the pressure adjusting control knob attached to the diaphragm. In two-stage pressure regulator, there are two safety valves so that if there is any excess pressure there will be no explosion. It also has an automatic compensation for any drop in the supply pressure. Two pressure gauges are also provided to show the inlet and outlet pressures. The cut sectional view of a two-stage pressure regulator is shown in Figure 3.3.

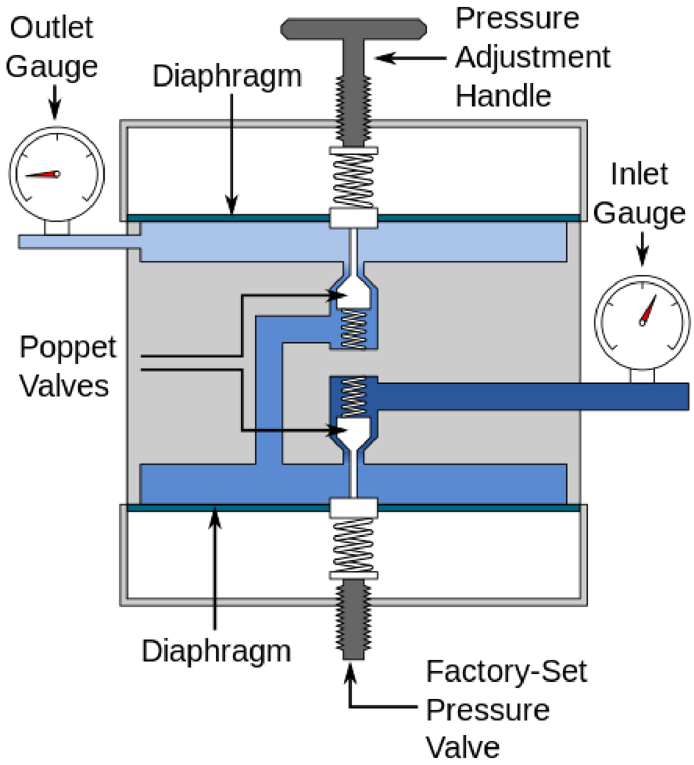

Figure 3.3. Two-stage pressure regulator

3.4. Oxygen flow meter

Oxygen flow meter is used to measure the flow rate of oxygen to the gasifier. It is connected between the two-stage pressure regulator and the flash back arrestor. The specification of oxygen flow meter which is used in the experimental set up is 0 – 50 litres per minute. The photographic view of oxygen flow meter is shown in Figure 3.4.

Figure 3.4. Oxygen flow meter

3.5. Flash back arrestor

A flash back arrestor is a special gas safety device most commonly used in oxy-fuel welding and cutting to stop flame or reverse flow of gas back up into the equipment or supply line and it prevents the user and equipment from damage or explosions. The photographic view of the flash back arrestor is shown in Figure 3.5.

Figure 3.5. Flash back arrestor

3.6. Gasifier

The gasifier is a cylindrical chemical reactor of co-current, updraft type with a feeding port at the top for charging biomass into the gasifier. Oxygen is supplied into the gasifier at two diametrically opposite points of the cylindrical gasifier just above the grate. The biomass is supported over the grate during its gasification. The ash formed during gasification is collected below the grate. The syn gas leaves the gasifier through an exit pipe provided at the top of the gasifier. Since the gas flows upwards inside the gasifier, it is said to be of updraft type. The photographic view of the oxygen-blown gasifier is shown in Figure 3.6.

Figure 3.6. Gasifier

3.7. Burner

The exit pipe of the gasifier is connected to a gas burner. It is a swirl type gas burner with tangential entry of both syn gas and combustion air through two different pipes at its bottom end. The tangential entry of both the fluid streams into the burner causes swirling motion of the mixture in the burner. Since the turbulence is high, better mixing is possible. The flame in the swirl burner is more stable than that in a straight flow burner. The flame stability is attributed to the formation of toroidal recirculation zones and to the reduction in combustion lengths. There is a high rate of entrainment of the ambient air and also fast mixing particularly near the boundaries of the recirculation zones. The photographic view of the burner is shown in Figure 3.7.

Figure 3.7. Burner

All the components discussed in Sections 3.2 – 3.7 were assembled together as per the schematic diagram shown in Figure 3.1 and the final experimental set up was established.

Chapter 4

EXPERIMENTATION

For conducting experiments in the oxygen-blown gasifier, silver oak wood was used. It is a soft wood variety. The wood was cut to pieces of size approximately 1.3 cm x 1.3 cm x 1.3 cm. The photographic view of the wood pieces used in the experiments is shown in Figure 4.1. If loose biomass like ground nut shells [9] are used, then biomass preparation cost can be avoided.

Figure 4.1. Wood pieces

Two types of experiments were conducted on the gasifier: (i) by supplying oxygen and (ii) by supplying air. In the former case, oxygen-blown gasification of wood pieces yielded a medium heating value gas called syn gas; whereas in the latter case, air-blown gasification of wood pieces yielded a low heating value gas called producer gas

4.1. Experiments by supplying oxygen to the gasifier

The gasifier was charged with charcoal pieces upto a certain height. The charcoal bed was ignited and the fire was allowed to spread through the bed by supplying oxygen from the oxygen cylinder through the pressure regulator and the flow meter. The oxygen pressure was reduced as it passed through the two-stage pressure regulator and the flow of oxygen was metered before supplying to the gasifier. Once red hot charcoal bed was established, wood pieces were fed through the feeding port into the gasifier. When the bed of wood pieces reached about 75 % of the height of the gasifier, feeding was stopped.

The oxygen flow rate was maintained at 10 lpm. Within a few minutes, vapours/gases emanated from the swirl burner. When ignited, the vapours/gases were burnt at the exit of the burner and the flame was stable. The photographic view of gasification system when supplied with oxygen is shown in Figure 4.2. The gasifier was operated till all the wood pieces which were initially charged got exhausted and the flame became extinct in the burner. The quantity of wood pieces charged into the gasifier, the oxygen flow rate and the time period of operation were measured during the experiment. The experiment was repeated again on two different days, during which the oxygen flow rates were maintained at 15 lpm and 20 lpm respectively.

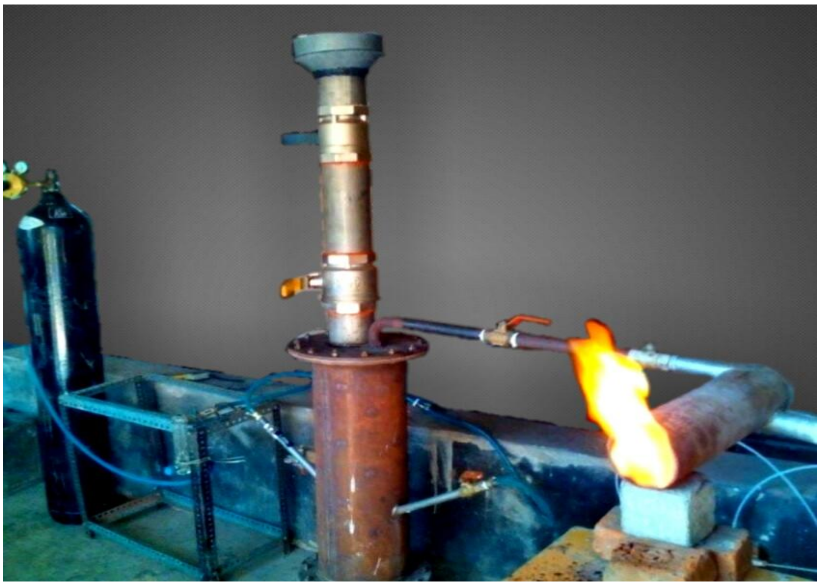

Figure 4.2. Photographic view of gasification system when supplied with oxygen

4.2. Experiments by supplying air to the gasifier

The schematic diagram of gasification system when supplied with air is shown in Figure 4.3. Initially, a storage tank was charged with compressed air to a pressure of 8 bar by running a reciprocating air compressor. Later, the storage tank supplied the air required for gasification of wood pieces. All the components of the oxygen-blown gasification system were retained in the air-blown gasification system also.

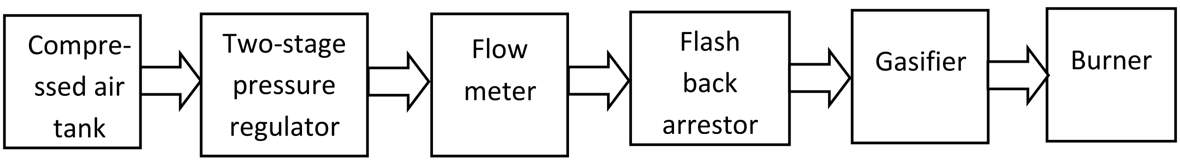

Figure 4.3. Schematic diagram of gasification system when supplied with air

The gasifier was charged with charcoal pieces upto a certain height. The charcoal bed was ignited and the fire was allowed to spread through the bed by supplying air released from the compressed air storage tank through the pressure regulator and the flow meter. The compressed air pressure was reduced as it passed through the two-stage pressure regulator and the flow of air was metered before supplying to the gasifier. Once red hot charcoal bed was established, wood pieces were fed through the feeding port into the gasifier. When the bed of wood pieces reached about 75 % of the height of the gasifier, feeding was stopped.

The air flow rate was maintained at 45 lpm. Within a few minutes, vapours/gases emanated from the swirl burner. When ignited, the vapours/gases were burnt at the exit of the burner and the flame was stable. The photographic view of gasification system when supplied with air is shown in Figure 4.4. The gasifier was operated till all the wood pieces which were initially charged got exhausted and the flame became extinct in the burner. The quantity of wood pieces charged into the gasifier, the air flow rate and the time period of operation were measured during the experiment. The experiment was repeated again on a different day, during which the air flow rate was maintained at 50 lpm.

Figure 4.4. Photographic view of gasification system when supplied with air

Chapter 5

RESULTS AND DISCUSSION

5.1. Gasification by supplying oxygen

The quantum of flow rate of oxygen to the gasifier is an important parameter. It has been calculated that about 1.37 kg of oxygen is required to completely oxidize 1 kg of dry wood pieces with an empirical formula of $CH_{1.44}O_{0.66}$. Assuming an equivalence ratio of 0.3 for gasification, the amount of oxygen required is 0.41 kg per kg of dry wood pieces. The calculation of mass ratio of O_2/wood pieces is significant in the control of gasification process.

Three trials were conducted on three different days. The oxygen flow rates were maintained at 10 lpm, 15 lpm and 20 lpm during the first, second and third trials respectively. The wood pieces used in the experiments had a bulk density of 240 kg/m^3. The amount of wood pieces stacked initially in the gasifier, at the beginning of the experiment, was constant in all the three trials. The experimental results for oxygen-blown gasification of wood pieces are given in Table 5.1.

Table 5.1. Experimental results for oxygen-blown gasification

Trial	Oxygen flow rate (lpm)	Duration of experiment (min)	Wood quantity (kg)	Wood consumption rate (kg/h)	Quantity of O_2 supplied during experiment (kg)	Thermal power rating (kW)
I	10	83	2.88	2.08	0.83	9.82
II	15	63	2.88	2.74	0.95	12.94
III	20	51	2.88	3.38	1.02	15.98

It can be seen that when oxygen flow rate was increased, the wood pieces could be consumed quickly; the wood consumption rate increased and consequently the thermal power output also increased. After each trial, the residual contents of the gasifier were extricated. The residues were found containing unburnt charcoal, ash and clinkers. The clinkers are formed as a result of melting or agglomeration of ash particles which occurs normally at high temperature. The presence of clinkers in the residues thus implies that the biomass bed temperature during gasification was higher than the ash fusion temperature of wood pieces. Figure 5.1 shows the clinkers formed during oxygen-blown gasification of wood pieces.

Figure 5.1. Clinkers formed during oxygen-blown gasification

Most of the time, the flame was very luminous and slightly bluish at the burner indicating that the flame temperature was high when syn gas was burnt. Only for a brief time period, the flame was less luminous and yellowish indicating that the flame temperature was less. The presence of significant amount of tar and particulate matter in the syn gas was the reason for the luminosity of the flame. When syn gas is directly burnt in a burner, the tar and particulate matter present in it do not pose any problem. But, if syn gas is to be used in an engine then the gas must be cleaned thoroughly.

5.2. Gasification by supplying air

The quantum of flow rate of air to the gasifier is an important parameter. It has been calculated that about 5.89 kg of air is required to completely burn 1 kg of dry wood pieces with an empirical formula of $CH_{1.44}O_{0.66}$. Assuming an equivalence ratio of 0.3 for gasification, the amount of air required is 1.76 kg per kg of dry biomass. The calculation of mass ratio of air/wood pieces is significant in the control of gasification process.

Two trials were conducted on two different days. The air flow rates were maintained at 45 lpm and 50 lpm during the first and second trials respectively. The wood pieces used in the experiments had a bulk density of 240 kg/m^3. The amount of wood pieces stacked initially in the gasifier, at the beginning of the experiment, was kept constant in both the trials. The results obtained for air-blown gasification of wood pieces for the two different air flow rates of 45 lpm and 50 lpm are given in Table 5.2.

Table 5.2. Experimental results for air-blown gasification

Trial	Air flow rate (lpm)	Duration of experiment (min)	Wood quantity (kg)	Wood consumption rate (kg/h)	Quantity of air supplied during experiment (kg)	Thermal power rating (kW)
I	45	83	2.88	2.08	4.5	9.82
II	50	70	2.88	2.47	4.2	11.64

It can be seen that when air flow rate was increased, the wood pieces could be consumed quickly; the wood consumption rate increased and consequently the thermal power output also increased. After each trial, the residual contents of the gasifier were extricated. The residues were found containing unburnt charcoal, ash and clinkers. The presence of clinkers in the residues implies that the biomass bed temperature during gasification was higher than the ash fusion temperature of wood pieces. L. Kumararaja and R. Sethumadhavan [10] measured the bed temperature distribution along the height of an air-blown gasifier at different times during the operation of the gasifier. They have not reported any clinker formation as the bed temperatures were lower in their experiments. Figure 5.2 shows the clinkers formed during air-blown gasification of wood pieces.

Figure 5.2. Clinkers formed during air-blown gasification

Most of the time, the flame was less luminous and yellowish indicating that the flame temperature was less when producer gas was burnt. The presence of tar and particulate matter in the producer gas was the reason for the luminosity of the flame.

5.3. Cost analysis

The total cost of gasification of wood pieces takes into account (i) the capital cost of the gasification system and (ii) the operating cost. The total cost can be evaluated in terms of (i) Rs./kg of wood pieces gasified or (ii) Rs./h of gasifier operation or (iii) Rs./kW of thermal power generation, etc. Since the life span of the gasifier is longer, the capital cost spread over the entire life span of the gasifier is very less. Hence, it is neglected for any simple cost calculation. So, the operating cost of the gasification system is often taken as the basis for comparison between different types of gasification systems. In the present project also, only the operating costs of oxygen-blown gasification system and air-blown gasification system for wood pieces are calculated and are compared.

Table 5.3. Comparison of operating costs

Oxygen-blown gasification		Air-blown gasification	
Item	Rs./kg wood gasified	Item	Rs./kg wood gasified
1. Cost of wood	4	1. Cost of wood	4
2. Cost of cutting wood to pieces	5	2. Cost of cutting wood to pieces	5
3. Cost of oxygen (0.41 x 50)	20.50	3. Cost of air supply (0.17 x 3)	0.50
Total operating cost	29.50	Total operating cost	9.50

It can be seen that Rs.5 are required for every kg of wood gasified in both the gasification methods due to the cutting of wood to pieces of dimensions 1.3 cm x 1.3 cm x 1.3 cm. If loose biomass like ground nut shells, cashew nut shells, etc. are used instead of wood pieces, then the cutting cost can be avoided. In oxygen-blown gasification, 70 % of the operating cost is due to the cost of oxygen used for gasification of wood pieces. If the oxygen cost is minimized, then it will make oxygen-blown gasification of biomass very attractive economically.

Chapter 6

CONCLUSIONS

From the literature, published already by the earlier researchers, it has been found that when oxygen is used as gasifying agent for wood pieces in a gasifier, the product gas will not contain nitrogen in it. The resulting gas is called as syn gas and it has a better heating value.

An experimental set up comprising of oxygen-blown gasifier and other basic accessories has been constructed. The gasifier has a maximum thermal power rating of 16 kW which is sufficient to drive a 4 kW engine.

From the experiments, it is concluded that oxygen-blown gasification of wood pieces can yield a good quality syn gas. It has good flame stability when burnt in a burner. The range of inflammability limits is also large. The syn gas can be used to drive an internal combustion engine after cooling and cleaning.

The operating cost of oxygen-blown gasification of wood pieces has been worked out to be Rs.29.50/kg of wood pieces gasified. But, the operating cost of air-blown gasification of wood pieces is Rs.9.50/kg of wood pieces gasified. If the cost of oxygen is reduced, then oxygen-blown gasification of biomass will become attractive economically.

REFERENCES

[1] Rivarolo, M. and Massardo, A. F. "Optimization of large scale bio-methane generation integrating "spilled" hydraulic energy and pressurized oxygen blown biomass gasification", International Journal of Hydrogen Energy, Vol. 38, pp. 4986-4996, 2013.

[2] Timothy C. Williams, Christopher R. Shaddix and Robert W. Schefer, "Effect of syn gas composition and CO_2-diluted oxygen on performance of a premixed swirl-stabilized combustor", Combustion Science and Technology, Vol. 180, No. 1, pp. 64-88, DOI: 10.1080/00102200701487061, 2007.

[3] Jeffrey Phillips, "Different types of gasifiers and their integration with gas turbines", EPRI, Advanced Coal Generation, Charlotte, NC 28221.

[4] Cuong Van Huynh and Song-Charng Kong, "Combustion and NO_x emissions of biomass-derived syn gas under various gasification conditions utilizing oxygen-enriched-air and steam", Fuel, Vol. 107, pp. 455-464, 2013.

[5] Amit C. Gujar, Jong Baik, Nathaniel Garceau, Nazim Muradov and Ali T-Raissi, "Oxygen-blown gasification of pine charcoal in a top-lit downdraft moving-hearth gasifier", Fuel, Vol. 118, pp. 27-32, 2014.

[6] Nazim Muradov, Amit Gujar, Jong Baik and Ali T-Raissi, "Production of Fischer-Tropsch hydrocarbons via oxygen-blown gasification of charred pinewood pellets", Fuel Processing Technology, Vol. 140, pp. 236-244, 2015.

[7] Simeone, E., Siedlecki, M., Nacken, M., Heidenreich, S. and W. de Jong, "High temperature gas filtration with ceramic candles and ashes characterization during steam-oxygen blown gasification of biomass", Fuel, Vol. 108, pp. 99-111, 2013.

[8] Atmadeep Bhattacharya, Abhishek Bhattacharya and Amitava Datta, "Modeling of hydrogen production process from biomass using oxygen blown gasification", International Journal of Hydrogen Energy, Vol. 37, pp. 18782-18790, 2012.

[9] L. Kumararaja and R. Sethumahavan, "Behavior of a woody and a loose biomass in a downdraft gasifier", Energy Sources, Part A: Recovery, Utilization and Environmental Effects, Vol. 36, No. 24, pp. 2736-2744, 2014.

[10] L. Kumararaja and R. Sethumadhavan, "Experimental studies on biomass bed height and certain process parameters in a fully co-current flow biomass gasifier", Energy Sources, Part A: Recovery, Utilization and Environmental Effects, Vol. 35, No. 10, pp. 945-954, 2013.