BIOMASS GASIFICATION AND RICE HUSK PRODUCER GAS

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Abstract:- Wood and charcoal gasifiers have played an important role during world war II, when liquid fuels for internal combustion engines were not available. Soon after the war with the availability of fossil fuels, interest on gasification has disappeared. With the increase in oil prices there have been renewed interest on gasification from the mid 1970's.

Those interested in the technology must accept that it demands hardwork and tolerance of soiled hands by a responsible operator and that it is not yet perfect. But it is both serviceable and economic in many applications in spite of its inconveniences.

INTRODUCTION

Gasification is the thermochemical process of converting chemical Energy in solid feedstock (such as coal, charcoal, wood, paddy husk etc) into gaseous Energy carriers. The gas thus produced is known as "producer-gas". This should be distinguished from biogas production which uses microbiological conversion process of wet organic feedstock to generate a combustible gas. Gaseous (and liquid) fuels are advantageous over solid fuels as they:-

(a) Burn with low excess air - high combustion efficiency.
(b) Could be easily controlled when feeding into combustion chambers.
(c) Leave no ash after combustion.
(d) Could be used in internal combustion engines as well.

The gasification of carbon containing fuels and the use of the gas in internal combustion engines is a technology which has been utilised for more than a century. The utilization has peaked during the second world war, when more than a million vehicles (buses, trucks, motor cars, boats and trains) were powered by gasifiers fueled by wood charcoal.

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After the war there was a complete reverse to liquid fossil fuels, as soon as they became available. The obvious reasons were their convenience, reliability and economic advantages. Thus the interest in gasification declined.

The high and escalating oil prices followed by the fuel crises in 1973 and 1979 had adverse effects on economies of oil importing developing countries. As a result, there has been increased interest in indigenous renewable Energy sources of which biomass in the form of wood or agricultural residues is the most readily available in many developing countries. In order to utilize biomass in place of petroleum fuel there was renewed interest on gasification technology.

THEORY OF GASIFICATION

In thermochemical gasification the solid feedstock successively undergoes:-

- Heating
- Devolatization - drying (70 - 170^{o}C)
  pyrolysis (170-400^{o}C)
- Gasification of remainder char (400-1000^{o}C)
- Thermal cracking (1000-1400^{o}C)

Pyrolysis is an intermediate stage of gasification.

SOLID + HEAT   CHAR + LIQUID (Tar & Water) GAS

That is the thermal degradation of solid material, yielding, CHAR as a residue condensable vapour (WATER & TAR) and gaseous components.

Solid fuels consist mainly of Carbon, Hydrogen and Oxygen ($C_xH_yO_z$). In addition there can be negligible quantities of Nitrogen and Sulphor. The proportion of these constituents differ from one to the other.

A controlled quantity of air is drawn into the gasifier allowing combustion of part of the feedstock generating heat, known as oxidation. The combustion gases then react with hot feedstock and gets reduced to form a mixture of Carbon Monoxide (CO), Hydrogen(H_2), and Methane (CH_4), known as reduction. This mixture amounts to about 35 - 40% of the total

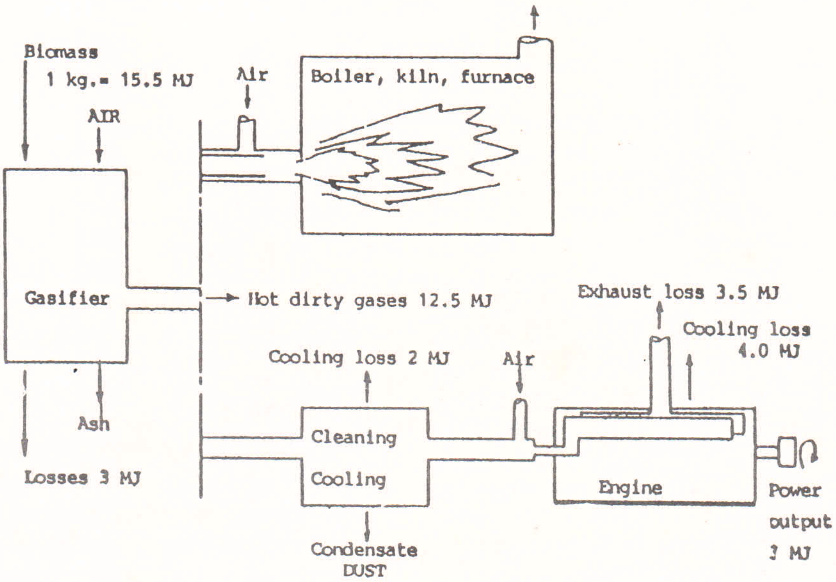

Fig 1 - Schematic diagramme of direct heat and power gasification systems

gas volume. The major component in the remainder is Nitrogen (N_2) derived from the air drawn in, and amounts to about 50 - 55% of the gas volume.

In complete combustion, Carbon dioxide (CO_2) is obtained from carbon and water from hydrogen. Oxygen in the fuel also reacts in the combustion process decreasing the amount of air demanded.

Oxidation or combustion is described by the following chemical reaction formulae.

$C + O_2$	CO_2	- 401.9 kJ/mol
$H_2 + 1/2O_2$	H_2O	- 241.1 kJ/mol

These formulae mean that burning 01 gram a ton, i.e. 12.00 g of carbon to dioxide a heat quantity of 401.9 kJ is released and that 241.1 kJ of heat results from oxidation of 01 gram molecule, i.e. 2,016 g of hydrogen to water vapour.

The most important reactions that take place in the reduction zone, among the gases and solid reactants are given below. A minus sign indicates that heat is generated in the reaction and a positive sign that reaction requires heat.

(a) $C + CO_2$	$2 CO$	+ 164.9 kJ/mol
(b) $C + H_2O$	$CO + H_2$	+ 122.6 kJ/mol
(c) $CO_2 + H_2$	$CO + H_2O$	+ 42.3 kJ
(d) $C + 2H_2$	CH_4	0
(e) $CO + 3H_2$	$CH_4 + H_2O$	- 205.9 kJ

Most gasification processes are auto-thermal. The heat necessary for endothermic gasification is accomplished internally by exothermic (combustion) reactions and hence are sometimes called gasification by partial combustion.

GASIFICATION TECHNIQUES

1. Fixed bed Gasifier
   - Up Draft
   - Down Draft
   - Cross Draft
2. Fludised Bed Gasifier
3. Entrained Flow Gasifier

Fixed Bed Gasifier

Fixed Bed Gasifiers are usually characterised by the direction of air (gas) flow inside the reactor namely up-draft, down-draft and cross-draft. Depending on whether the feedstock moves in the opposite direction or in the same direction as that of air, they sometimes are classified as counter current or co-current gasifier, respectively.

The up draft gasifier is the simplest of the three types but it tends to produce a very dirty gas in terms of its tar content etc. unless a high quality charcoal is used. This type is therefore normally restricted to direct heat applications.

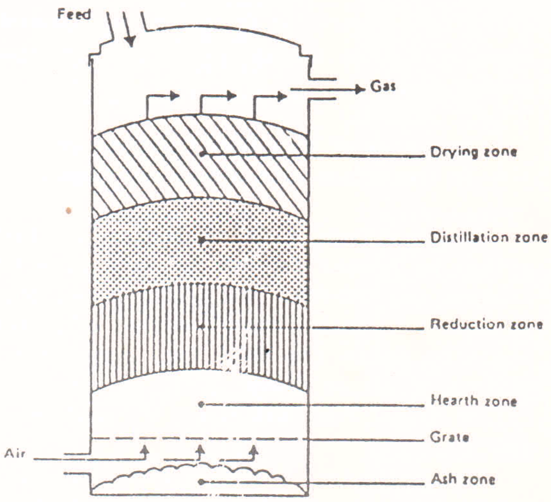

Fig 2.1 - Updraft or counter current gasifier

The down draft gasifier is the most common because, when working properly, it produces a virtually tar free gas, a pre-requisite if the gas is to be used for shaft power applications. The majority of the gasifiers used during World War II were of this type. It can use a large variety of feedstock (solid biomass) but is more difficult to control than the up draft gasifier.

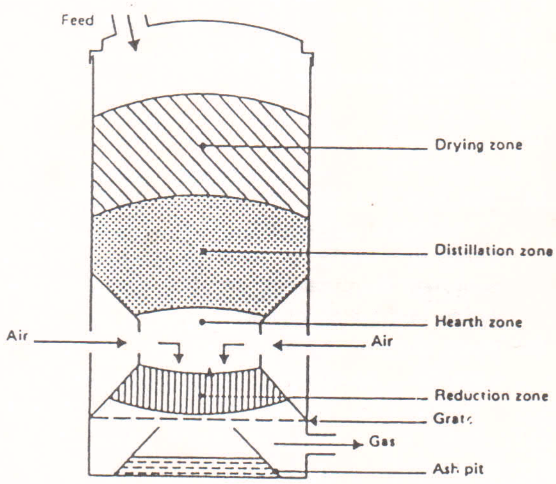

Fig 2.2 - Downdraught or co-current gasifier

- The cross draft gasifier was originally designed for use in vehicles because it is light and gives a rapid response to changes of the load on it. However, it requires a high quality charcoal as feedstock.

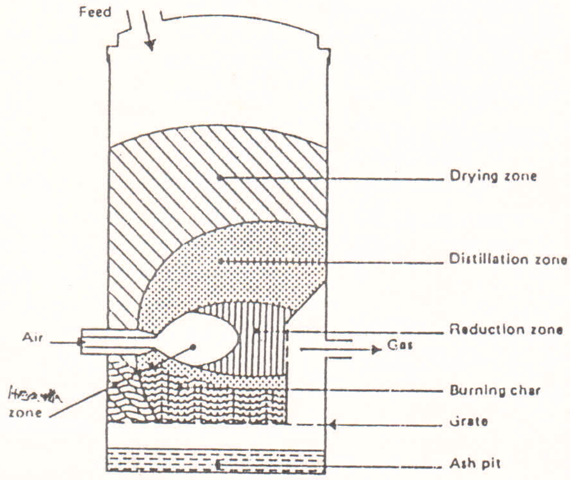

Fig 2.3 - Cross-draught gasifier

Fluidised Bed Gasifier

Air is blown from below through a distributor plate which is at the bottom of the reactor. The feedstock is kept in suspension by the upward flow of air. The zones are similar to that of fixed bed up-draft gasifier reactor.

Entrained Flow Gasifier

These gasifiers are suitable for power generation applications and their capacities range from 50 to 150 MW. The working temperature is fairly high around 1600°C and the gas flow relocity is 20 to 50 m/s. In most cases, oxygen is injected in place of air for effective combustion.

GASIFICATION FUELS

Biomass fuels available for gasification include charcoal, wood waste, coconut shells, coconut husks, cereal straw and rice husk.

Because those fuels differ in their chemical, physical and morphological properties, they make different demands on the method of gasification and hence require different reactor designs or even gasification technologies.

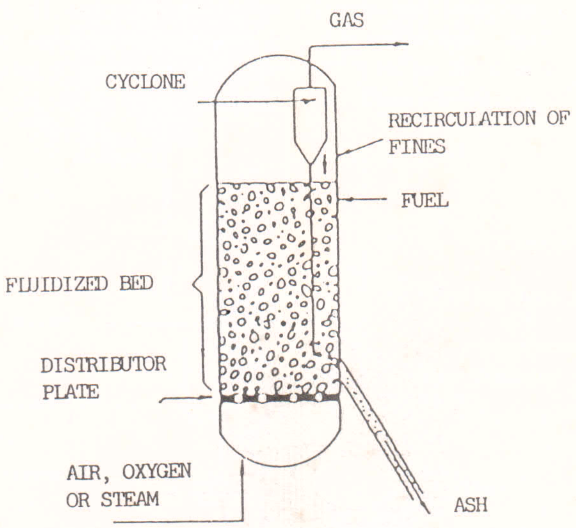

Fig 3 - Fluidized bed gasifier

Thus it follows that the "universal" gasifier, able to handle all or most fuels or fuel types does not exist.

Each type of gasifier will operate satisfactorily with respect to stability, gas quality, efficiency and pressure losses only within certain ranges of fuel properties of which the most important are,

- Energy content
- Moisture content
- Volatile matter
- Ash content and ash chemical composition
- Reactivity
- Size and size distribution
- Bulk density
- Charring properties

Before choosing a gasifier for any individual fuel, it is important to ensure that the fuel meets the requirements of the gasifier or that it can be treated to meet these requirements.

RICE HUSK GASIFIER INSTALLED AT PATTIYAPOLA

The Energy Unit of Ceylon Electricity Board, Sri Lanka has designed and constructed a paddy husk gasifier and installed at its Rural Energy Centre (REC), Pattiyapola (in Hambantota District). Technical assistance was provided under the Netherlands - Sri Lanka Energy Programme for this project.

This is a fixed bed, down draft (co-current) gasifier. The total cost of fabrication and installation was around Rs. 100,000/- . The gasifier was utilised to fuel the existing "Ford/Onan" Spark ignition engine generator ususally run on biogas and " Lister" diesel engine generator.

Economics of Rice Husk Gasification in Comparison with Biogas and Diesel

The Ford/Onan gasoline engine is fueled either by biogas (BG-FG) or with rice husk producer gas (RG-FG). The Lister Diesel engine is used (as a normal diesel engine) only diesel fuel (D) or in the dual fuel mode using a mixture of either diesel fuel and biogas (BG-DF) or diesel fuel and rice husk producer gas (RG-DF).

The following specific fuel consumption values (all per kWh of electrical output) are based on data collected from REC, Pattiyapala.

Fuel gas operation		**Feedstock per kWh output**
(BG-FG)	Cowdung for biogas	0.65 cubic foot
(RG-FG)	Ricehusk	3.75 kg
Duel fuel operation		
(BG-DF)	Cowdung for biogas	0.52 cubic foot and
	Diesel fuel	0.08 litre
(RG-DF)	Ricehusk	2.9 kg and
	Diesel fuel	0.08 litre
Diesel Fuel operation		
(D)	Diesel fuel	0.42 litre

(a) The electricity supply is given to the Pattiyapala village from 18.00 hrs to 22.00 hrs daily (4 hours a day). As such, manpower requirement for the gasifier operation was taken as one person a day.

(b) When biogas is used, two persons per day have been accounted for as large amounts of cowdung (700 to 800 kg) have to be mixed with water and fed each day into the digestor.

(c) The fuel costs are based on actual inclusive of transport cost to REC (Rice husk is considered available free).

(d) The maintenance costs have been taken as a percentage of the investment cost. This is not very correct as it now implies that maintenance is a fixed cost independent of the number of running hours.

(e) The investment costs of the engine and generators, biogas installation etc. have been calculated at 1988 prices.

	Fixed bed down draft	Flluidised bed	Enterained flow flow
Practical size	1 - 10 cm	0 - 2 cm	less than 200 cm
max. ash content	less than 6% wt.	less than 25% wt.	less than 40% wt.
Char residence time	upto 1 hr.	10 - 20 sec.	a fraction of a second
Gas phase residence time	1 second	1 second	a fraction of a second
Operating temp.	800°C-1400°C	800°C-900°C	1200°C-2000°C
Control	Simple	Intermediate	Complex
Material of construction	mild steel and refractory	heat resistant steel	heat resistant steel and refractory
Capacity	upto 2.5 MW	1 - 50 MW	upto 150 MW
Start up time	Minutes	Hours	Days
Attendants	Low	Intermediate	High
Gas tar content	less than 250 mg/Nm^3	less than 500 mg/Nm^3	0
Typical gas low heat value	(based on saw dust) 4500 kJ/Nm^3	(based on sawdust) 5100 kJ/Nm^3	(based on sawdust) 4000 kJ/Nm^3

Table 1 - Parameters of different gasification systems

Investment	Lifetime years	Full Gas Operation Biogas	Full Gas Operation RH Gas	Dual Fuel Operation Diesel	Dual Fuel Operation Biogas	Dual Fuel Operation RH Gas
Ricehusk gasification unit	5		100,000			75,000
Biogas digestor 85 cubic meter	15	250,000			250,000	
Gas engine Ford/Onan 37.5 kVA	10	400,000	400,000			
Diesel engine Lister 24 kVA	10			240,000	240,000	240,000
Building and site	25	100,000	50,000	40,000	100,000	50,000
TOTAL INVESTMENT		750,000	550,000	280,000	590,000	365,000
OPERATING COST FACTORS FOR BASE CASE						
Cost of ricehusk delivered to site Rs./kg	0.10					
Cost of cowdung delivered to site Rs./kg	1.00					
Cost of diesel fuel per litre	8.13					
Manpower cost/manday in Rs. and no. required	35.00	2	1	1	2	1
Maintenance cost as % of investment cost		3.5	7.5	2.5	3.5	7.5
Number of running hours per day	4.0					
Capacity required in kW_{el}.	8.0					
Interest rate in %	20.00					
COST PER KWH GENERATED IN BASE CASE		19.79	17.11	10.71	16.53	12.45

Table 2 - Comparison of Biogas, Diesel Fuel Ricehusk Gasification in Pattiyapola (All costs in SLRs.)

In Table 2, for the different options all the relevant investment - and cost data, manpower - and maintenance requirements, number of running hours and the load on the system can be found. It has been assumed that the gasifier unit is running for 360 days per year which is high but is coupled with a low amount of running hours, which results in 1,440 hours of operation per year. With this data, the electricity cost price per kWh_{el} has been calculated which also can be found in Table 2 (base case)..

When looking at the electricity supply from the different options available, it is seen that the cost of electricity generated with the diesel engine only, is by far the cheapest, followed by the duel fuel system with ricehusk producer gas. It is also clear that in the case where the diesel engine is used, the electricity cost in general is lower than in the case in which the full gas engine is used. The reason for this is the lower investment cost coupled with the low number of running hours as shown in the following.

System	BG-FG	RG-FG	D	BG-DF	RG-DF
Cost per kWh_{el}			(Rs. Cts.)		
Capital cost (fixed)	14.67	12.06	5.68	11.36	8.02
Operating cost (variable)	5.12	5.05	5.03	5.17	4.43
Total per kWh_{el}	19.79	17.11	10.71	16.53	12.45

Table 3 - Structure of electricity cost for the base case

However in the case where more kilowatt hours would be generated, either by letting the unit run over a longer period or by having a larger load during the same period (not possible in most cases), we see a complete different picture. This can be amply demonstrated by using again the base case but only changing the number of running hours to 12 instead of 4 hours as in the base case. This is shown in Table 4.

System	BG-RG	RG-FG	D	BG-DF	RG-DF
Cost per kWh_{el}			(Rs. Cts.)		
Capital cost (fixed)	4.89	4.02	1.89	3.79	2.67
Operating cost (variable)	2.87	2.30	4.27	3.24	2.48
Total per kWh_{el}	7.76	6.32	6.16	7.03	5.15

Table 4 - Structure of electricity cost with 12 hours/day running

The operating cost using the different options in the base case did not show large variations but this has now changed in such a way that the diesel engine has become by far the most expensive to operate. In fact this system is no longer the cheapest but it has been overtaken by the case where the diesel engine is used in the dual fuel mode using ricehusk gas.

HEALTH AND ENVIRONMENT HAZARDS ASSOCIATED WITH THE USE OF PRODUCER GAS

Toxic Hazards

An important constituent of producer gas is carbon monoxide, an extremely toxic and dangerous gas because of its tendency to combine with the heamoglobin of the blood and prevent oxygen absorption and distribution. A summary of the effects caused by different concentrations of carbon monoxide in the air is given in Table 5.

Fortunately, normal producer gas installations work under section, so that even a minor leak occurs in the installation, no dangerous gases will escape from the equipment during actual operation. The situation is different however during starting-up and closing down of the system.

Fire Hazards

Fire hazards can result from the following causes.

- High surface temperature of equipment
- Risk of sparks during refuelling
- Flames through gasifier air inlet on refuelling lid

Explosion Hazards

Explosion can occur if the gas is mixed with sufficient air to form an explosive mixture.

This could occur for several reasons.

- Air leakage into the gas system
- Air penetration during refuelling
- Air leakage into a cold gasifier still containing gas which subsequently ignites
- Backfiring from the fan exhaust burner when the system infilled with a combustible mixture of air and gas during starting-up

Air leakage into the gas system does not generally give rise to explosions, if the temperature is low.

Percentage of CO in air	ppm	effects
0.005	50	no significant effects
0.02	200	possibly headache, mild frontal in 2 to 3 hours
0.04	400	headache frontal and nausea after 1 to 2 hours, in the back of the head after 2.5 to 3.5 hours
0.08	800	headache, dizziness and nausea in 45 min. collapse and possibly unconsciousness in 2 hours
0.16	1600	headache, dizziness and nausea in 20 min. collapse, hours
0.32	3200	headache and dizziness in 5 to 10 minutes, unconsciousness and danger of death in 30 minutes.
0.64	6400	headache and dizziness in 1 to 2 minutes, unconsciousness and danger of death in 10 to 15 minutes.
1.28	12800	immediate effect, unconsciousness and danger of death in 1 to 3 minutes.

Table 5 - Toxic effects of different concentrations of carbon monoxide in the air

Environmental Hazards

During the gasification of wood and/or agricultural residue, ashes and condensate are produced. The latter can be polluted by phenolics and tar.

The ashes do not constitute an environmental hazard and can be disposed of in the normal way. For the tar containing condensate the situation is different, and disposal of those can have undesirable environmental effects. Sri Lanka Standards 652: 1984 gives tolerance limits for industrial wastewater discharged into inland surface waters.

CONCLUSIONS

Biomass in the form of wood, charcoal and coconut shell are not in abundance supply. There are large volumes of agro residues such as rice husk, coir dust, crop wastes etc. available in some areas. In the south, rice husk is burnt to get rid of it. In coconut growing areas, coir dust mountains are growing in length, breadth and height.

Development of suitable gasification technologies in order to utilize biomass which is now wastefully destroyed could be one of the solutions to provide small power requirements in isolated locations. Producer gas for shaft power and electricity generation needs further improvements in gas cleaning systems. In direct heat applications, it could substitute furnace oil or firewood with a few alterations to the system and it is very economical.

REFERENCES

[1] Report on "Rice Husk gasification Project REC Pattiyapola", Ceylon Electricity Board, 1988.

[2] Wood gas as engine fuel, FAO forestry paper No. 72, 1986.

H N N Fonseka is a mechanical engineer attached to the Energy Unit of Ceylon Electricity Board. He is actively engaged in biomass Energy activities. He is an associate member of Institution of Engineers Sri Lanka. From 1980 to 1985 he was attached to the wind mill project of Water Resources Board and has contributed to development of wind pumps for lift irrigation.

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