CHAPTER II

SOME ASPECTS OF BIOMASS GASIFICATION

At the beginning of this century solid fuels were rather inexpensive when compared to liquid fuels and it was economical to convert solid fuels like coal, coke, wood, charcoal, crop residues etc. by a gasification process into combustible gases to power internal combustion engines.

The definition of "gasification" restricted here to the process occuring in gas producers means the conversion of solid fuels into gaseous fuels by conserving an optimal quantity of chemical energy. Considering a fuel mainly consisting of carbon, the conversion is accomplished by the partial combustion of the carbon component into carbon monoxide. To improve the efficiency of this partial combustion even further the heat generated is further used to dissociate water vapor, which is usually present, into hydrogen and oxygen.

A suitable producer gas for internal combustion engines usually consist of about 20 to 28 vol% CO, 12 to 18 vol% H_2 and 1 to 5 vol% gaseous C_mH_n while the rest is nitrogen. The hydrogen content accelerates the combustion process in the internal combustion engine while CO and CH_4 contribute to a high knock resistance. The producer gas obtained from the gasification process is a low calorific value gas, because air having a high nitrogen content is used in the partial combustion process.

In Thailand, development of gasifiers have been reported from various sources such as the Agriculture Technical Department, Ministry of Agriculture and Cooperatives, from entrepreneurs in Bangkok, in Kanjanaburi, and in Chachensao Provinces, and from Prince of Songkla University in Songkla Province. The main use of gasifiers are for industrial shaft-power generation for rural areas where grid electricity is either expensive or unavailable, for operating electricity generators, for shaft power for irrigation pumps where diesel fuel is expensive. At present, the most attractive biomass used as fuel for gasifiers in Thailand are wood, wood charcoal and rice husk.

Wood Gasifiers

Wood has an ash content of less than 1% and a bulk density somewhat less than one gram per cubic centimeter. And when chipped to desired size can be gasified properly only in downdraft gasifiers (Kaupp and Goss, 1981 ; Seri, 1979 ,Foley and Bernard, 1983). The main feature of such gasifiers consists of a throat made up of a choke plate or some other constrictions in the middle of which temperatures are very high (perhaps above 1000°C) and through which nearly all passing volatiles should be cracked into a gas. The resulting gas would be relatively free of tar, particularly at full load operation. It is quite difficult to start wood gasifiers and operate them satisfactorily due to the presence of volatiles in the gas. The maintenance of these gasifiers is more elaborate than other gasifiers. The theoretical overall system efficiency is 85% based on bone dry wood as material (Arthayukti, 1984).

Charcoal Gasifiers

Charcoal is traditionally gasified in updraft, crossdraft and downdraft fixed bed gasifiers. These gasification systems are characterised by the relative simplicity in the design, operation and maintenance, which make them particularly suitable for rural areas where there is abundance of forest wood supply and availability of charcoal making methods. The charcoal gasifiers require a quicker start-up time, minimal maintenance and less elaborate cleaning due to low tar content of the producer gas. The theoretical overall system efficiency is about 72% based on bone dry charcoal as raw material. Based on wood as the raw material, and including the conversion loss to charcoal we still get half of the efficiency when using wood (Arthayukti, 1984).

Rice Husk Gasifiers

Rice husk are considered to be difficult to gasify in fixed bed gasifiers, mainly because of low density, poor flow characteristics, high ash content and low melting point temperature of the ash. These serious problems can be effectively solved by using a fluidized bed gasification technique. The fluidized bed gasifier, also, can be easily operated at relatively low temperature (around 800-900 $^{\circ}C$) which is well below the fusion temperature of most types of ashes and slags. The gasifier efficiency is about 57.4% based on dry rice husk which may have a calorific value of 14.70 MJ/KG (Arthayukti, 1984). The fluidized bed-rice husk gasifier is attractive in areas where rice mills exist, especially to run gasoline engines for shaft power in the mill. An overall efficiency of the system at 1500 rpm has been reported at 5.08% when operated on producer gas compared to 20.07% when operated on regular gasoline. This is due to the energy conversion loss from rice husk to producer gas which mainly depends on the efficiency of the fluidized bed gasifier.

Conversion of Internal Combustion Engines from Gasoline and Diesel to Producer Gas

One of the most attractive applications of producer gas is its use in internal combustion engines for shaft-power generation. However, there are many questions that should be looked into before attempting to run an internal combustion engine with an alternative fuel such as a producer gas. The producer gas-air mixture as delivered to the combustion chamber is certainly inferior in some respects to the gasoline-air or diesel-air mixture for which most engines have been designed.

There is a significant difference between a diesel and spark ignition engine with respect to suitability for producer gas operation. Diesel engines operate on the compression-ignition principle, drawing in a full unthrottled charge of air during the intake stroke. A compression ratio between 12 and 20 is used to achieve a high air temperature at the end of the compression stroke. Just before top dead center, the diesel-air mixture is sprayed into the combustion chamber and the fuel burns almost immediately without any spark ignition. This will not be the case with a producer gas-air mixture. In fact, a diesel engine cannot be operated on producer gas alone because the gas-air mixture will not ignite at the prevailing compression temperature and pressure. Spark ignition engines do not have this disadvantage and can be operated on producer gas alone without any pilot injection of gasoline. The two cases of conversions are as follows (Kaupp and Goss, 1981) :

1. <u>Conversion of a gasoline engine to producer gas</u>

Today's compression ratio for spark ignition engines lies within the range 5 for industrial and tractor engines and 10 for premium gasoline passenger cars. The expected power drop for an unaltered engine will be about 40%. There are four alternatives to recover part or all of the power loss :

1.1 No modifications of the engine. In this case recovering of the power loss means driving the engine at a higher speed on a continuous basis.

1.2 Supercharging or turbocharging the engine.

1.3 Supercharging or turbocharging the engine and supercharging the gas producer.

1.4 Increasing the engine compression ratio.

1.5 Dual fueling the engine.

The use of an unalternated gasoline engine for producer gas operation is appealing from an economical point of view and is technically sound. This approach is, in particular, beneficial in cases where an existing unit is operated on half load most of the time and the full power requirement is not crucial. There is a considerable diversion of opinions as to what extent the recovery of the power is actually useful. The actual efficiency of the gasoline engine will be only slightly affected or may be even better for producer gas operation. It therefore makes sense to anticipate the expected power drop in a new installation and choose a larger engine to meet the power output requirements and extend the life of the unit.

2. Conversion of diesel engine to producer gas

Diesel engines are compression ignition engines and operate at a much higher compression ratio (16-20) depending on whether they are direct injection chamber, pre-combustion chamber, four stroke or two stroke engines. Diesel engines cannot be operated on producer gas without injection of a small amount of diesel oil because the producer gas will not ignite under the prevailing pressures. A diesel engine needs to be dual fueled or completely converted into a spark ignition engine. One can convert a diesel engine to producer gas as follows :

2.1 Rebuilding of the entire engine with a new piston and new cylinder head and installment of electric ignition equipment. The power drop in diesel engines converted to spark ignition operation is not as severe as in gasoline engines operated on producer gas. A relative power output of 70-85% at low speeds and 60-80% at high speeds is a result not readily obtainable with gasoline engines, even if they are dual fueled.

2.2 An alternative method of effecting diesel conversion for the use of producer gas is by retaining the existing compression ratio and arranging for dual fueling. In this case the fuel injection system is retained together with the original pistons and modifications confined to a special induction manifold and a gas-air mixer as in converted gasoline engines. Direct injection engines, although they are working at high compression ratios compared to gasoline engines, are more suitable compared to other types of diesel engines and do not require special low compression ratios as long as the compression ratio does not exceed 16 to 17. A marginal power loss of 5% to 10% was reported, depending on the heating value of the producer gas. The pilot injection of diesel oil amounted to 16-28% of the original consumption or 10 mm^3 to 17.5 mm^3 per cycle.

<u>Cost Aspects of Gasification Systems</u>

Apart from price variations which stem from differences in the manufacturer's marketing strategy or from the use of differently priced components like engines and electricity generators, price differences between systems can generally at least in part be explained by posing oneself the following two questions :

1. How complete is the system and which components are used?

Some manufacturers quote systems inclusive of automatic fuel feeding devices, automatically rotating grates, self cleaning filters etc., while others present this equipment as optional extras which do not directly show up in the price. Sometimes the necessary gasifier control equipment as well as electrical components are quoted as separate items and as such do not show up in the costs of the installaton. Finally the overall system cost depends to some extent on the type of engine (gasoline, diesel or gas) offered.

2. How is the system capacity defined?

Especially in medium/large developped country build systems there may be an appreciable internal power consumption from ancillary equipment like automatic fuel feeders, cooling fans, water pumps etc. This means that there may be a considerable difference between the system's gross and net power output. Sometimes manufacturers quote a gross system capacity, while in fact the useful installed capacity is considerably smaller.

Cost Factors of DC and LDC Manufactured Gasification Systems

Systems manufactured in LDC's are in general appreciably cheaper than plants fabricated in DC's. In part those differences may be explained by a combination of the following factors :

1. As far as power applications are concerned, manufacturers from LDC's in general offer small-scale charcoal fueled systems (< 100 KW). With one or two exceptions, the main interest of manufacturers from DC's is in wood/waste gasifiers in the capacity range above 100 KW. Charcoal gasifiers normally will be cheaper than wood/ waste gasifiers, due to the fact that this feedstock allows a simpler reactor design and a smaller and less sophisticated gas treatment section.

2. Those manufacturers from LDC's fabricate gasifiers in small series. In DC's the gasifier market has not developed sufficiently to allow manufacturers to quote on basis of mass production. It is obvious that mass production can lead to substantial decrease in equipment costs.

3. Differences in labor and material cost levels may result in lower overall costs for equipment manufactured in a number of LDC's, especially in India and the countries of South-East Asia.

4. However sometimes a difference in workmanship and quality may be noticable between gasifier plants manufactured in DC's and LDC's. This can be expressed in factors like overall system life-time and repair and maintenance requirements. The aspect can be an argument by manufacturers from DC's in order to explain price differences.

Techno/Economic Requirements of LDC Gasification Systems

The techno/economic outlines of a gasification system suitable for LDC application must bear the following characteristics :

1. Very simple reactor design excluding complicated constructions like double walls for air-preheating and expensive insulation. Although those features increase fuel efficiency and improve gas quality, in most cases they cannot be economically justified.

2. Reactor construction from cheap and easily workable materials like mild steel and refractory are often recommended.

3. Expensive automatic systems like fuel feeders, rotating grates and self cleaning filters may not be economic in LDC applications.

4. Systems should have a good gas treatment section

both with respect to gas quality (tars and dust) and lifetime (corrosion). This may mean that expensive materials and/or unusual construction techniques may have to be used.

5. From a point of view of engine investment costs, full-gas operation is only attractive in a capacity range up to about 50 KW. The reason being that in such a case relatively cheap mass produced engines can be used. Larger systems preferably have to be run in "dual-fuel" (diesel) operation.

Main Parameters for Economic Analysis

A general economic analysis may be of restricted value for actual project decisions, due to the fact that actual conditions may differ from the ones assumed in the evaluation. Nevertheless an economic evaluation is usefull for establishing the relative importance of a number of cost factors. Besides it presents a useful methodology which can be followed in the prefeasibility stage of a real project. The key assumptions for the main parameters used in the economic evaluation are discussed below.

1. Equipment capital costs

Annual capital charges (A) are the initial investment costs (I) annualized over a period equal to the lifetime of the system at the prevailing interest rate. They are calculated using the relationship :

$$A = I \times \frac{r}{1-(1+r)^{-DV}}$$

The estimated investment cost for various types of gasifiers in different capacities are summarized below (Stassen, unpublished ; Coovattanachai and Sthiarphan, 1984) :

Types	Capacity	Specific investment cost (BT85/KW)
Charcoal gasifier	600 W	16,000
	2 KW	14,500
	5 KW	13,500
	10 KW	12,635
Wood gasifier	5 KW	23,400
	10 KW	20,615
	25 KW	16,900
	50 KW	13,965
Rice Husk gasifier	10 KW	20,615
	25 KW	16,900
	50 KW	13,965

2. Annual operating period and system lifetime.

The gasification systems were assumed to run for 2880 hours per year and with replacement after 6 years for a small capacity system up to 10 KW, and 8 years for higher capacity. This is equivalent to eight hours of operation per day and 360 operating days a year.

3. Fuel consumption

Diesel engines are supposed to consume about 0.45 litres diesel fuel per kilowatt-hour generated and dual-fuel diesel engines continuously consume 20-30% of the maximum diesel fuel consumption at full power output when operated in a full diesel mode.

The biomass consumption of the different systems was supposed to be as follows :

3.1 Full gas systems

- charcoal gasifier : 0.8 KG/KWH
- wood gasifier : 1.4 KG/KWH
  (Stassen, unpublished)
- rice husk gasifier : 2.1 KG/KWH

3.2 Dual fuel systems

- wood consumption : 1.4 x 0.7 KG/KWH
  or 1.4 x 0.8 KG/KWH

4. Fuel and lubrication costs

A lubricant cost of 0.2128 BT/KWH was assumed. The cost of diesel depends on the world price and government policy and this price varied between 6.3-6.7 BT/LIT during the period studied (1985-1989). The cost of biomass depends on the resource area, transportation and fuel preparation i.e. sizing and drying. The shadow prices of biomass were assumed as follows :

- charcoal 1.3-2.0 BT/KG
- wood 288-797 BT/TON
- rice husk 139-615 BT/TON

5. Operating labour for operation and maintenance

Manpower requirements for operating and maintenance of a gasification system are difficult to estimate, due to the lack of reliable data with regards to operating systems.

The manpower requirements for manual fuel feeding, starting the system, cleaning of filters, removing of ashes and draining of condensates are 0.1 hour per opertional hour for small systems up to 10 KW and 0.25 hour per operational hour for larger systems up to 50 KW. (Stassen, unpublished)

6. Manpower costs

There are great variations of manpower costs in the different areas where the gasifiers are introduced. These affect quite significantly the total gasification system cost.

7. Maintenance, repair and service

The costs of maintenance, repair and service of a gasification system are another cost aspect which are at present virtually unknown. Sometimes they are estimatd as 10% of the capital cost of the gasification system, which lead to the strange result that the cheapest system shows the lowest maintenance, repair and service costs. The average value of such costs is 0.72 BT/KWH.

The economic evaluation of total power costs for some gasification system compared to the conventional diesel units have already been performed. (Foley, Barnard, 1983 ; Stassen, unpublished ; Arthayukti, 1984).