A Research on Producer Gas in Internal Combustion Engines

Uppalapati.Babu, L. Kumararaja

ABSTRACT---Energy is a crucial requirement for economic and social improvement of any country. Sky rocketing of fossil fuel prices has lead to rising interest in various alternative fuels like producer gas, CNG, alcoholic fuels, vegetable oils. Producer gas is relatively a low calorific value fuel gas which can be used in compression ignition and spark ignition engines. Producer gas will be generated from any carbonaceous material as well as from different types of biomass. The engine power de-rating is usually 15-30% when producer gas is used in CI engines instead of diesel. It is mainly because of the variation in stoichiometric air/fuel ratio requirements for producer gas and diesel.

Keywords - Biomass, Internal combustion engine, Engine power, Producer gas.

I. INTRODUCTION

Biomass is considerate as one type of renewable source of energy with great possible to supply the world energy requirements [1]. The application of biomass will offer a lot of positive solutions - a renewable supply of energy services, together with heat, power, and transportation fuels, which reduce the effects due to carbon dioxide and sulphur dioxide emissions into the atmosphere. It also will gives energy security and increase rural economy through the substitution of coal, crude oil and gas. Worldwide biomass positioned fourth as energy resources, providing around 14% of the total world energy requirements. Biomass is significant sources of energy for which are developing countries, giving 35% of their total energy [2, 3].

Gasifier unit is a one of the chemical reactor, where the biomass materials like Rice Husk, Wood, Charcoal, etc. be able to converts into a fuel in the gaseous form are called producer gas, which contain hydrogen, carbon monoxide, methane, nitrogen, and carbon dioxide. This fuel contains a calorific value of 4 to 5 MJ/m3 can burnt directly with high efficiency. It has the flame temperature is about 1100°C.

Gasification process is not regarded as a brand new technology since it was already utilised during the Second World War. Throughout this era, a variety of vehicles in Europe were powered with charcoal gasifier (ANON-FAO Report, 1986). It is evaluated that more than seven million vehicles in South America, Europe, Pacific Islands and Australia were changed over to run on the producer gas for the duration of Second World War.

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II. KNOWLEDGE REVIEW FOR PRODUCER GAS UTILIZATION

The main technologies presently used to convert biomass to energy are thermo-chemical and biochemical conversion processes. The main types of thermo-chemical conversion technology of biomass in to energy are drying, pyrolysis, combustion, and reduction processes.

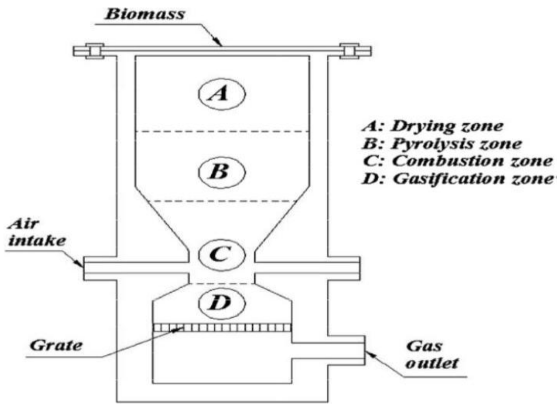

Fig.1: Downdraft Gasifier

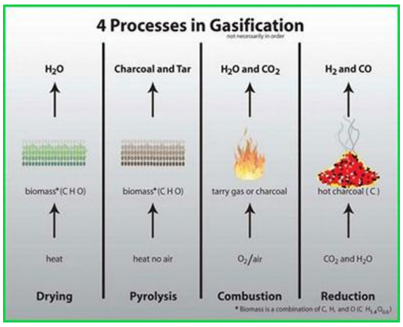

Fig.2: Four processes in gasification

A. Drying zone

In this section, the biomass is brought at top place of the gasifier. Because of the heat from lower part of a gasifier, the biomass gets dried in drying portion [4–8]. The moisture from the biomass flows downwards in form of vapour and enters into the oxidation zone.

Feedstock (moist) + Heat → Feedstock (dry) + H_2O (1)

B. Pyrolysis zone

In this zone, the temperature is more than 250°C; due to the high temperature causes the biomass feedstock decomposition is occurs. Here large particles are split into

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medium size particles (volatiles) and carbon (char) [4–9]:

Feedstock (dry) + Heat → Carbon (Char) + Volatiles (2)

C. Combustion zone

In this zone, oxidation or burning of char and volatiles occurs, due to the supply of air or oxygen. These combustion reactions are highly exothermic and cause a rapid temperature rise to 1100-1500°C [4, 8]. The reactions are [22, 23]:

$C + O_2 \rightarrow CO_2$ + 393 kJ/g. mole (3)

$2H_2 + O_2 \rightarrow 2H_2O$ + 242 MJ/kg mole (4)

In addition to generate heat, another important function of this zone is to oxidize almost all condensable products coming from the previous zone.

D.Reduction zone

In this zone, heat taken from oxidation zone is converted into the chemical form of the syngas or producer gas. The following equations take place [22, 23]:

$C + CO_2 \rightarrow 2\,CO$ (–172.6 kJ/g. mole) (Boudourd reaction)6)

$C + H_2O \rightarrow CO + H_2$ (− 131.4 kJ/g. mole) (Water gas reaction) (7)

$CO + H_2O \rightarrow CO_2 + H_2$ + 42.3 kJ/g. mole (Water gas shift reaction) (8)

$C + 2H_2 \rightarrow CH_4$ + 75 kJ/g. mole (Hydro gasification reaction) (9)

This mixture of gases known as syngas or producer gas

III. TYPES OF GASIFIERS:

There are various types of biomass gasifiers. They are broadly classified into fluidized bed and fixed bed gasifiers [10]. On the basis of flow direction of the gasesthrough the fixed bed of biomass, the gasifiers are classified as a) updraft, b) downdraft and c) cross draft. Gasifiers can also be classified on the basis of the type of oxidizing agent used, like air, oxygen or steam.

A. Updraft gasifier

The updraft gasifier is shown diagrammatically in Fig.3

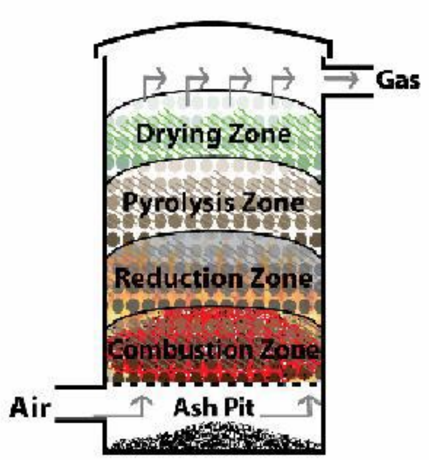

Fig.3: Updraft gasifier

It is the least complex type of gasifier. It contains a fixed bed of fuel. The gasification agent i.e., air is entered at the base, streaming upwards in counter-current direction with respect to the feedstock, which is supplied into the reactor from the top. The fuel goes progressively downwards through drying and pyrolysis where it is degenerated into solid char and volatile gases. After pyrolysis, the char undergoes endothermic gasification reaction in the place of reduction zone. In the oxidation zone, the ignition of char happens close to the mesh and the hot burning gases exchange warmth to the char. The producer gas generation is high because of high char conversion and due to that the gas leaves at a generally low (300-400°C).

B. Downdraft gasifier

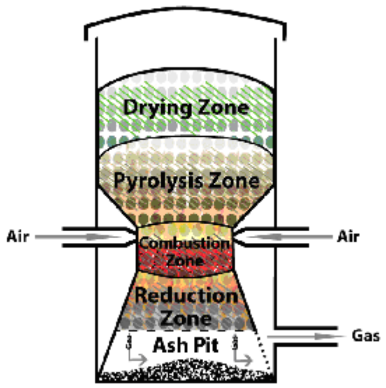

Fig.4: Downdraft gasifier

It is called co-current gasifier; it is the most widely recognized type of gasifier. In this gasifier, reduction section is under combustion zone. Fuel is feed at the top of gasifier. The air flows downwards throughout the combustion and reduction regions. In this gasifier air and fuel moves same direction then it is called co-current gasifier. This system is designed such that tar is formed within the pyrolysis zone, and goes throughout the combustion section; here it is burnt or split down. Accordingly, the blend of gases which leave the gasifier is clean. The producer gas contain only very little amount of tar, and hence it is appropriate for gas engines.

C. Cross-draftgasifier

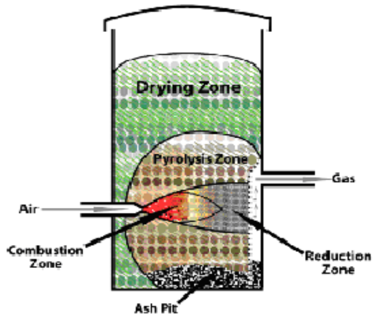

Fig.5: Cross-draft gasifier

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In this gasifier, air enters and leaves in opposite direction of the gasifier. This gasifier has a couple of unique favorable conditions like, lesser requirement for gas cleaning. Mesh is not necessary since the slag tumbles to the base and does not come in contact with the producer gas at the exit.

D. Fluidized bed gasifier

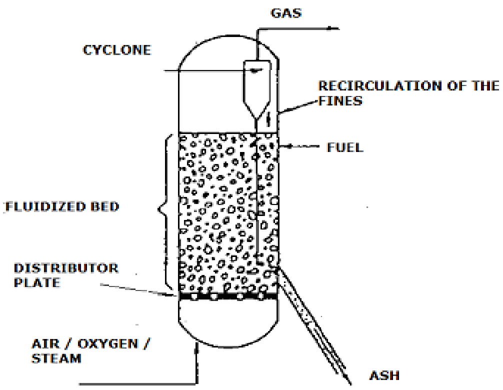

Fig.6: Fluidized bed gasifier

In this gasifier, the biomass bed is fluidized by supplying air. This bed is kept at a temperature range between 550°C and 1000°C. At this temperature, the fuel is feed into the gasifier, its drying, pyrolyzing reactions occur quickly, driving off volatiles even at moderately low temperatures. The rest of the biomass is oxidized inside the bed to give the heat for the drying and devolatilizing processes to proceed. These gasifier main functions as a hot bed of sand particles and biomass particles disturbed continually through air. Air is supplied throughout spouts situated at base of the gasifier bed.

E. Entrained-flow gasifiers

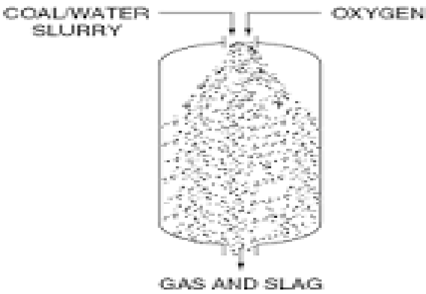

Fig.7: Entrained-flow gasifier

In this gasifier, fuel and air are fed at top place of the reactor, and fuel is conveyed by the air with in the reactor. The working temperatures range of 1200–1600°C and the pressure range contain between 20–80bar. In this Entrained-stream gasifier can be utilized fuel has in dry condition. Because of the small residence time, high temperatures are required for such gasifier. The benefit of this gasifier is that the gas has very minute amount of tar.

Advantages and disadvantages of different gasifier types

Type of gasifier	Advantages	Limitations
Updraft	Easy design	High amount of pyrolysisproducts and tar
	High quantity of charcoal flame-out	wide-ranging of gas cleaning required if usefor power application
	Fuel to gas transformation efficiency is more	
	High moisture content fuel are accepted	
	Various sizes fuels are accepted	
Downdraft	Less quantity of tar	Scales forming partially
	It is good for utilization of gas in engines	More tar produced at low temperature ranges.
	Less particles available in the gas, at low load conditions	Higher amounts of ash and dust
		Fuel supplies are very difficult
Cross-draft	It is applicable for Small scale process.	Large quantity of tar produced
	At higher temperatures, the gas cleaning not effectively required.	
Fluidized bed	Construction is compact.	Fine dust particles contains by the gas stream
	temperature profile Uniform.	Fuel bed holds less quantity of biomass. So This system is more complex.
	Accepts different fuel size particles.	Variety of biomass can be applicable but fuel flexibility is possible for biomass size of 0.1 cm to 1 cm.
	Does not lead to clinker formation at ash melting point of biomass.	
Entrained-flow	It is Applicable for big systems	Initial cost is high.
	Biomass residence time is very small.	Fuel requirements are very strict.

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IV. PROPERTIES OF PRODUCER GAS

A. Physical properties of producer gas:

Parameters	Symbol	Units	Value
Stoichiometric air-PG ratio	$(A/F)_{stoi}$	kg air/kg PG	1.01
Adiabatic Flame Temperature	T_{adfl}	K	1770
Wobbe Index	WI	kJ/m³	4171
Laminar burning velocity	S_L	m/s	0.45
Molar specific heat capacity at constant pressure at NTP	c_{pm}	kJ/(kmol.K)	30.36
Molar specific heat capacity at constant volume at NTP	C_{vm}	kJ/(kmol.K)	22.05
Mass density at NTP	ρ	kg/m^3	1.03
Absolute viscosity	μ_m	kg/(m.s)	$1.57263x10^{-5}$
Thermal conductivity	k_m	W/(m.K)	0.0344
Diffusion coefficient	$D_{air-mixt}$	m^2/s	$0.209x10^{-4}$
Specificgravityat NTP	SG	-	0.87

B. Chemical properties of producer gas:

Parameters	Symbol	Units	Value
Carbon monoxide	CO	vol %	17 - 22
Hydrogen	H_2		12 - 20
Methane	CH_4		2 - 4
Carbon dioxide	CO_2		9 – 15
Nitrogen	N_2		50 – 54
Water vapor	H_2O		4- 8
Molar mass	M	kg/kmol	25.14
Lower heating value	LHV	kJ/m³	5000 -5900

Producer gas consists of mixture of hydrogen, methane, carbon monoxide, nitrogen, and carbon dioxide. In that mixture hydrogen, methane, and carbon monoxide are combustible gases, whereas carbon dioxide and nitrogen are non-combustible gases. It has low heating value; the range of value is 5 - 6 MJ/m^3 depending upon its constituents.

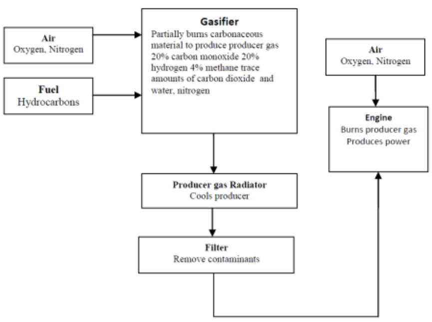

Fig.8: Process diagram showing gasification and producer gas utilization in engine

V. PRODUCER GAS IN COMPRESSION IGNITION ENGINES

C I engines with producer gas are more efficient, due to their low rotational speeds and high compression ratio, the de-rating of diesel engines operating on producer gas is below 30%. However, CI engines cannot be utilized without considering an appropriate procedure to begin the combustion, since the temperature toward the completion of compression stroke might be lesser than producer gas auto-ignition temperature. For that reason, one of the appropriate procedures is to run the compressed ignition engine on dual fuel mode [19]. The utilization of alternative fuels drive power creation is attracting a rising consideration from researchers and renewable energies specialists. Profits with the dual-fuel mode contain quieter and smoother operation, fuel savings and the probability to attain very minute emissions level, mostly in terms of particulate matter and smoke [20]. Modeling of the ignition process of a dual fuel engine operates with producer gas present some peculiarity that needs understand the heat discharge rate with in abnormal combustion. In this dual fuel combustion, the producer gas is the primary fuel and it is introduce along with air. It provides promising energy input to the heat engine. A small quantity of diesel fuel required in order to start the ignition of producer gas. The flame front propagation of air- producer gas mixtures depends up on the self-ignition temperature of the mixture. There are four stages in Combustion mechanism after fuel injection inside the engine cylinder [21]. Various research articles report the experimental data [22] dealing with the combustion characteristics of dual fuel. The plan of the work to be describe right modeling parameters and modeling approaches to evaluate the performance of engine as a function of the diesel fuel substitution rate.

VI. PRODUCER GAS IN SPARK IGNTION ENGINES

Compared with petroleum derivatives, the power de-rating in producer gas fuelled engine is predominantly cause by the low energy density per blend unit volume (30% and above [13, 16]) and by the fall in volumetric efficiency. Fuel transformation efficiency K_f also contributes to energy de-rating as well. From the basis of the data existing in the literature, K_f might decrease from 10% to 20% when compare to fossil fuel process [13, 14]. Generally, the power de-rating can vary from 30% to 70%, depending on the producer gas quality [15, 16], and can be fairly reduced by increasing the engine compression ratio. In reality, N_2 and CO_2, which constitute 60% of producer gas volume, this constitute act as the knock suppressor when compared to NG [13, 16]. In [17] the authors established that producer gas engine can run steadily under lean state, even though K_f decrease when O exceeds 1.5.In that paper, the emissions and performance of a heavy duty producer gas fuelled SI engine were analyses and compared to natural gas fuelled SI engine. From the observations power de-rating throughout

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producer gas operation exceed 50% because the reduction of volumetric efficiency, and reduced both NO_x and CO emissions [18].Except for CO_2, producer gas generates lesser quantity of pollutant emissions when burnt in IC engines in contrast to petroleum products [13]. In fact, combustible parts in producer gas are generally basic compounds (simple to oxidize), and burning temperature is moderately low, limiting the NO_x production.Simulation was done under over a range and full load of engine speeds. From simulated results, it had been establish that the simple mathematical model can predict the performance of gas engine and it gave good experimental results. The differences were within ±7% [12]. In [24], the author determined the BP of four strokes Honda GX-120 Model, spark ignited engine with producer gas at variable compression ratios. From the observations the engine had highest brake power at high compression ratios.

VII. CONCLUSION

Producer gas can give a promising energy source for the operation of compression ignition and spark ignition engines. By using Producer gas in IC engines, one can reduce the consumption of petrol and diesel. Engine power de-rating is about 15% - 30%, when producer gas is used as sole fuel in a CI engine. In addition, operation of producer gas engines requires a good understanding of operational parameters of the biomass gasifier. Producer gas also results in lower emissions to air.

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