A TECHNICAL REVIEW OF PRODUCER GAS AS AN ALTERNATIVE FUEL FOR INTERNAL COMBUSTION ENGINE.

Mahida Hirenkumar Ranjitsinh[1*], Rajesh C. Iyer[2#]

[1]Shroff S.R. Rotary Institute of Chemical Technology, Ankleshwar, Gujarat,
[2#]Founder-Chairman , CYRA Engines Private Limited, Surat, Gujarat
Email: hiren.mahida@gmail.com, rajesh_c_iyer@yahoo.com

Abstract

This paper describes the current state of available gasification technology for utilizing producer gas for I.C engine application & different ways to optimize the performance. Producer gas is promising alternative fuel to meet energy demand in many countries which is defined as gas generation from solid waste through thermo chemical conversion route (also termed as gasification) can be used for fuelling a compression ignition (CI) engine in duel fuel mode or a spark ignition (SI) engine in the gas alone mode. This technology is also environmentally benign and holds large promise for the future. This paper summarizes the work conducted using biomass derived producer gas in reciprocating internal combustion engines. Survey in the field of producer gas based engines reveals modest research work have been carried out since the inception of biomass/ charcoal gasification systems. Producer gas contains a large fraction of inert (> 50%) and with laminar burning velocity being high (due to presence of H_2), smooth operation at higher Compression ratio does not seem impossible. These aspects are very vital in establishing the fact that close to comparable power (with a lesser extent of de-rating $\sim$ 15-20%) with producer gas by operating in engine at higher compression ratio. This could be attributed to two reasons, namely non- availability of standard gasification system that could generate consistent quality producer gas and the other relating to misconceptions about producer gas (related to compression ratio limitation due to knock tendency and de-rating). The knock tendency can be expected to be better on account of large fraction of inert gas as compared to natural gas. However, there has not been any research on octane rating test conducted on producer gas fuel and moreover it is not clear if any established test procedure exists for producer gas like the methane number test for natural gas and biogas. De-rating could be due to reduction in the mixture energy density and the product-to-reactant mole ratio. If one were to summarize earlier studies, it becomes evident that no systematic investigation has been attempted so far in identifying if limitation of knock exists with producer gas operation at compression ratio comparable with the diesel engine operation.

Keywords: Producr gas, Knocking, De-rating, Gasification, Compression ratio

I. INTRODUCTION

With the renewed interest in the biomass energy by necessity, biomass based technologies are achieving prominence not only a rural energy devices but also as industrial power plants. Gasification is one such process where clean gas could be generated using a wide variety of bio-residues as the feed stock and in turn uses the fuel gas for power generation purposes. These are being used in standard diesel engines in duel fuel mode of operation and in petrol engines in gas alone mode. In the present times, adopting these technologies has immense economic benefits, a route pursued by a number of researches in it.

Development of gas engines using producer gas has been explored ever since World War II. It is estimated that over seven million vehicles in Europe, Australia, South Africa and Pacific Islands were converted to run on producer gas during World War II. These engines were spark ignited engines, mostly in the lower compression ratio bracket operating either on charcoal or biomass derived gas. Extensive fieldwork has been carried out at National Swedish Testing Institute of Agriculture Machinery, Sweden (ANON-FAO Report,1986) by mounting gas generators and engine set on trucks and tractors as sited by Martin et al.(1981)

At the far end of 20th century, there was a renewed interest in biomass gasification technology, which had stimulated interest in producer gas operated engines. Prior to 21st century, the work reported in this area had been limited to lower Compression Ratio (CR) (less than 12.0) engine due to perceived limitations of knock at higher CR. The other important reason that appears responsible in the non-availability of standard and proven gasification systems, which could generate gas of consistence quality on a continuous basis for engine applications. A short review of earlier studies, related to producer gas engine is presented in the following section in order to explain the context for this topic.

II. REVIEW OF PAST EXPERIMENTS

A large number of researches were carried out with biomass as a replacement of internal combustion (IC) engine fuel from various parts of the world. Most of these experiments were reported from USA, Europe, India, Malaysia, China and Germany. A summary of these experimental results are discussed in this paper. Literature survey in the field of producer gas based engines reveals modest research work to have been carried out since the inception of biomass / charcoal gasification systems. This could be attributed to two reasons, namely non availability of standard gasification system that could generate consistent quality producer gas and other relating to misconceptions about producer gas fuel.

Martin et al. (1981) had conducted experiments using charcoal gas and biomass based producer gas on a SI engine and had found a de-rating of 50% and 40 % respectively at a CR of 7. They also claimed a 20% de-ration while working with producer gas at a CR of 11. An upper limit of CR of 14 and 11 for charcoal and biomass based producer gas respectively was proposed by Martin et.al.

Parke et al. (1981) worked on both naturally aspirated andsuper charged gas engines. The de-ration of 34% was claimed compared to gasoline operation and a lesser de-rating in a supercharged mode.

In the Indian sub-continent, work in the area of producer gas engine has been reported by the biomass gasification group at the Indian Institute of Technology, Mumbai. Experiments were conducted on a naturally aspirated diesel engine at CR of 11.5 (Shashikant et al. 1993, 1999; Parikh et al. 1995). The reason given for limiting the CR was knocking tendency. However, no experimental evidence was provided in support of it.

The only earlier experimental work in the higher CR range is reported by Ramachandran (1993) on a single cylinder diesel engine with a CR 16.5 coupled to a water pump. A power de-ration of 20% was reported at an overall efficiency of 19% without any signs of detonation. However this work does not report detailed measurement of gas composition, pressure crank angle diagram and emissions, which are essential for systematic investigation and scientific understanding.

Experimental results of a systematic investigation on producer gas operated internal combustion engine at higher CR for the first time was reported by Sridhar et al.(2001). The primary investigation was conducted on an engine of 24 kw capacity. Experiments were conducted on a spark ignition engine converted from a naturally aspirated, three cylinder, direct injection diesel engine (RB 33 model) of compression ratio CR 17. It was reported that working at a higher CR turned out to be more efficient and also yielded higher brake power.A maximum brake power of 17.5 KWe was obtained at an overall efficiency of 21% at the highest CR. The maximum de-rating of power in gas mode was 16% as compared to the normal diesel mode of operation at a comparable CR, whereas, the overall efficiency declined by 32.5%.

Also a systematic investigation on produce rgas operation at CR comparable to that of diesel hy`engine was carried out and reported by Sridhar et al. (2001,2003,2006). The source of producer gas fuel used was from an open top re-burn down draft gasifier system using casuarina wood pieces as fuel source. The compression ratio limits were tested up to 17:1 without any audible knocking. It was demonstrated that the comparable power to that of diesel engine (with lesser de-rating of ~15-20%) could be achieved with producer gas by operating engine at higher CR.

In 2005, Sridhar et al. investigated on a naturally aspirated engine (Ashok Leyland make – ALU680 model) to study the gaseous emissions of producer gas driven by IC engine and found that in duel fuel operation NOx levels are lower compared to operations with pure diesel fuel on account of lower peak flame temperature. The CO levels were higher due to combustion inefficiencies. In the case of gas alone operation, it is found to be environmentally benign in terms of emissions; NOx and CO levels are found to be much lower than most of the existing emissions norms of various countries including the USA and EU.

Jaun J. Hernandez et al. (2005) had tried to estimate the laminar flame speed of producer gas using CHEMKIN software, together with GRI-Mech Chemical reaction mechanism, and found that the flame speed of the producer gas is less than that of iso-octane but greater than that of methane.The analysis shows that the dominant chemical reactions and species have a major influence on the laminar flame speed of producer gas at different producer gas/air equivalence ratios. Although good qualitative agreement has been found, some differences between experimental and modeled results at high pressure and temperature are due to the instabilities in the experimental flame.

For the first time, experiments on internal combustion engine with moving bed gasifier had been conducted by F.V. Tinaut et al. (2006) and they found that the characteristics of the gasification gas that affect the most quantitatively the engine power are the heating value, the stoichiometric air-fuel ratio and the volume correction factor. Also two zone thermodynamic model predicts the engine performance which includes the fraction of mass burned, the pressure and temperature evolution and the pollutant emissions.

S. Dasappa et al. (2007) had hands on the CUMMINS naturally aspirated engine at Indian Institute of Science, Banglore to check the wear of the components assessed at the end of 5000 hours of operation. They had observed that the monitoring and reliability studies indicate that the wear of the engine's components to be with well within limits. Engine lube oil quality has been periodically assessed and found to be satisfactory. The pressure curve is smooth and there is no knock inside the cylinder.

A. Ramadhas et al. (2008) carried out several experiments on Canon make four stroke direct injections naturally aspirated, single cylinder, C.I engine of 5.5 KW to check the performance on dual fuel mode operation. They have concluded that higher the capacity of the engine than the required capacity to be selected because the producer gas dual fuel engine could run only at maximum of 50 – 60% of maximum load condition. The power generation cost while using biomass is much cheaper than the conventional power generation cost.

Name of Author & Year	Working Area	Outcomes/ remarks
S. Dasappa et al. (2007)	CUMMINS SI engine to check wear of different components.	Wear of all components is within limit.
A. Ramadhas et al. (2008)	CANON make DI engine (5.5 KW) to check performance of duel fuel mode.	PG duel fuel engine could run only at maximum of 50 - 60% of maximum load condition.
Sridhar et al. (2005)	Ashok Lelland make- ALU680 model to study the gaseous emissions of PG engine.	NO_x levels are lower compared to operations with pure diesel fuel. CO levels are higher due to combustion inefficiencies.
Sridhar et al. (2001)	Kirloskar (RB 33) 3 cylinder , DI engine of Compression ratio 17.	Working at higher CR turned out to be more efficient and also yielded higher brake power.
Jaun J. Hernandez et al. (2005)	CHEMKIN software, together with GRI-mech chemical reaction mechanism for finding flame speed.	Flame speed of PG is less than isooctane but more than methane.
Ramachandran (1993)	Single cylinder diesel engine with CR of 16.5 coupled to a water pump.	Power de-rating of 20% was reported at an overall efficiency of 19%.
Shashikant et al. (1993,1996)	Naturally aspirated diesel engine at CR of 11.5	Find the limiting CR for knocking tendency.
Parke et al. (1981)	Works on both naturally aspirated and super charged gas engines.	De-rating of 34% was claimed compared to gasoline operation and a lesser de-rating in a supercharged engine.

However , a combination of the ignition voltage, compression ratio (CR) and piston crown geometry in the performance and emission characteristics of a CNG engine with an improvement by 20-30% under certain cases with a considerable reduction in emissions as compared to conventional gasoline was reported by Rajesh C. Iyer et al.

III. RESULT & DISCUSSION

A. Advantages

From the review of literature available in the field of biomass energy, many advantages are noticeable. The following are some of the advantages of using biomass as fuel with Internal Combustion engine in India.

- India is an agriculture based country so agricultural waste obtained domestically helps to reduce costly petroleum imports.
- Development of the biomass usage machinery would strengthen the domestic, and particularly the rural, agricultural economy of agricultural based countries like India.
- Producer gas has reasonable cetane number and hence possesses less knocking tendency.
- This technology is environment friendly due to absence of sulphur content.
- No major modification is required in the existing technology.
- Producer gas dedicated engine technology could be operated and manage by the local people.

B. Challenges

The major challenges that face the use of Producer gas as I.C engine fuels are listed below.

- Compatibility with I.C engine material needs to be studied further.
- Acceptance by engine manufacturer is another major difficulty.
- Feedstock homogeneity, consistency and reliability are questionable.
- Analyze the combustion techniques in combustion chamber with different composition of producer gas.
- Study the effect of piston geometries, compression ratio, ignition timing, ignition voltage requirements, effect of bore to stroke ratio in context to the fuel gas composition and air fuel ratios on the engine performance.
- To develop a scrubbing technology to reduce impure gases in the stream and to optimize the fuel composition and improve the engine performance.
- Finally, to evolve a configuration for the engine design that stands as the best fit for a Producer Gas Engine technology deemed as a Dedicated Engine for PG.

C. Technical Difficulties

- Co- product utilization like ash produced in a beneficial manner.
- Emission testing with a wide range of biomass feed stocks to establish the emission standards like fossils fuel standards.
- Continued engine performance, emissions and durability testing in a variety of engine types and sizes need to be developed to increase consumer and manufacturer confidence.
- Environmental benefits offered by biomass over diesel fuel needs to be popularized and some subsidies must provided to the people who use producer gas dedicated engine.
- Studies are needed to reduce the cost and identify potential markets in order to balance cost and availability.

IV. CONCLUSION

Researchers in various countries carried out many experimental works using producer gas derived biomass as I.C engine fuel substitutes. It has been observed that most engines running on producer gas are diesel substitute and a de-ration of 40-50% has been reported by all major researchers even after augmenting the CR. Thus, results have shown that the thermal efficiency was comparable to that of I.C engine with small amounts of power loss while using producer gas. The particulate emissions of producr gas are lesser than that of the diesel fuel with a reduction in NOx and producer gas from biomass gave performance characteristics comparable to the petrol and diesel. Hence, they may be considered as diesel substitutes. The use of producer gas derived from biomass as I.C engine fuels can play a vital role in helping the developed world to reduce the environmental impact of fossil fuels as well for developing countries to be self dependent in producing electricity from waste to fulfill the basic need of every human being.

REFERENCES

[1] A.S. Ramadhas, S. Jayraj, C. Muraleedharan (2008) : Duel fuel mode operation in diesel engines using renewable fuels: Rubber seed oil and coir-pith producer gas, *Renewable Energy 33,*PP 2077-2083.

[2] Francisco V. Tinaut, Andres Melgar, Alfonso Horrilo, Ana Diez de la Rosa (2006) : Methods of predicting the performance of an internal combubstion engine fuelled by producer gas and other low heating value gas, *Fuel Processing Technology* 87, PP 135-142

[3] G. Sridhar, P.J. Paul, H.S. Mukunda (2001): Biomass derived producer gas as a reciprocating engine fuel-an experimental analysis, *Biomass and Bioenery* 21, PP 61-72

[4] G. Sridhar (2003) Experiments and modelling studies of producer gas Gas based Spark Ignited Reciprocating Engines. *PhD Thesis,* Indian Institute of Science , Banglore, India.

[5] G. Sridhar, S. Dasappa, H.V. Sridhar, P.J. Paul, N.K.S Rajan (2005): Gaseous emissions using producer gas as fuel in reciprocating engines*, SAE Technical Paper* 2005-01-1732.

[6] Juan J. Hernandez, Magin Lapuerta and Clara Serrano (2005): Estimation of the laminar flame speed of produce rgas from biomass gasification, *Energy & Fuels* 19, PP 2172-2178.

[7] Martin J. and Wauters P. Performance of Charcoal Gas Internal Combustion Engines, *Proceedings of International Conference- New Energy Conversion Technologies and Their Commercialization,* Vol 2, PP 1415-1424

[8] Parke P.P. and Stanley S.J. and Walawnder W. (1981): Biomass producer Gas Fuelling of Internal Combustion Engine*, Energy from Biomass and Wastes* V, Lake Buena Vista PP. 1 – 35.

[9] Parikh P.P., Banerjee P.K.,Shashikantha and Veerkar S. (1995): Design development and optimization of a spark ignited producer gas engine, *Proceedings of XIV national conference of IC engines and combustion,* Pune, India, Vol 14, PP 97-107.

[10] Ramachandran A. (1993) Performance studies on a wood gas run IC engine, *Procedings of Fourth National Meet on Biomass Gasification and Combustion,*Mysore, India Vol 4, PP 213-218

[11] Rajesh C. Iyer, Mallikarjun Vaggar, T.R. Seetharam, Salim Abbasbhai Channiwala (2008): Investigation of the influence of Ignition Voltage, Highrt Compression Ratio and Piston Crown Geometry on the performance of Compressed Natural gas Engines, *SAE 2008-01-176.*

[12] Shashikantha, Banerjee P.K., Khairnar G.S., Kamat P.P. and Parikh P.P. (1993): Development and Performance Analysis of a 15 KWe Producer Gas Operated SI Engine, Proceedings of Fourth national Meet on Biomass Gasification and Combustion, Mysore, India, Vol. 4, PP. 219 - 231.

[13] Shashikanha and Parikh P.P. (1999) Spark Ignited Producer gas and Dedicated CNG engine- Technology development and Experimental Performance, *SAE 1999-01-3515 (SP 1482).*