EMISSION & PERFORMANCE ANALYSIS OF PRODUCER GAS AS IN IC ENGINE FUEL: A TECHNICAL REVIEW

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Abstract. For the sake of eco-friendly and large promise to be used in future producer gas plays an important role. It is prepared by gliding air and steam through the thick coal at different temperature range. A gasifier is used to gasify biomass such as rice husk, bagasse, wood chips. Due to inertness knocking tendency is higher in producer gas, use of producer gas tends to higher emission of CO, especially at lean condition. It results in rigorous environment damage. The use of producer as an alternative fuel is founded as the sustainable source of energy.

1. Introduction
As our country is the Biggest Producer of husk, straw etc. But still they are not utilized properly, so it is being used for making producer gas. In 1914 - 18 producer gas was introduced, but in world war second it was used widely in Europe, North America and Australia, producer gas was used in more than 1 million vehicles. Again the producer gas was seen in internal combustion engine in 1973 during the oil crisis. It is was not so much successful because during operation, the power should de-rated. The producer gas has low energy density as compared to other fuels like natural gas, diesel & gasoline (3,4). Producer gas is made by biogas’s partial combustion. Such a process is known as Gasification.

Gasification is the process to convert the carbonaceous fuels into gaseous compound by providing less amount of oxygen which is necessary for the complete combustion of that fuel. By the conversion of fossil into CO, CO2, H. The output we get is Producer Gas. It is done at more than 700°C. Normally the temperature range is 1112°F-2732°F. It is used in dual mode engine in order to produced power and electricity. Gasification involves heating, pyrolysing partially oxidizing & reduction. The heating valve of output gas is found to be 950-1200KCa/m3. The calorific value of producer gas is very less. Composition of Producer Gas are:- CO (18-22%), H (9-13%), CH3(1-5%), HC(0.2-0.4%), CO2(9-12%), N(22-45%), H2O(4%).

There are several type of gasifier such as fluidized gasifier, fixed bed gasifier. There are three types, namely, up draft type, down draft type and cross draft type gasifier. Among the all, the down draft fixe bed gasifier is most preferable as there is less tar formation and need of cleaning is reduced.
2. Literature Review:

2.1. G.Sridhar [1]
Tested an engine at higher C.R. i.e. 17:1 for restrict the knock in the engine. Producer gas has calorific value 4.7-5.0 MJNm⁻². Variation in C.R. affects the engine’s power output. Turbulent flame speed is the important factor affecting the rate of releasing the heat during process of combustion in the engine. The laminar speed of flame is decreased by 1/10 by increasing the initial pressure by 40 for the producer gas and air mixture. Growth in flame rate lead to increase in radicals released for C.R. 17:1, the output we get is 17.5 kW with overall efficiency 21%. It is compared with engine 21 kW with overall efficiency 31%. Overall efficiency means the shaft output per unit energy content. Efficiency and output is proportional to the compression ratio. At 18% efficiency, we get maximum output of 15.3 kW at C.R. 11.5:1.

2.2. Praveen Pandey [2]
Describes that producer gas made by rice husk replaced the diesel about 31% during operation in the dual fuel engine, the soot formation is much less when the proper supply of oxygen is given with that of producer gas. In gasifier we feed the waste products and after combustion of these product we get producer gas and then Scrubber, condenser, char and fabric filter are used to remove the Particulate impurities, water particles, moisture and fine dust respectively. After that the producer gas will supply to engine with diesel and then flue gas will test by Exhaust gas analyzer. On using diesel fuel and producer gas simultaneously then the opacity of exhaust gas increased and as the quantity of producer gas increases the opacity becomes maximum. If the less amount of nitrogen is present in biomass gasifier then the obtained producer gas which further mixed with diesel, the mixture has high calorific value. The parameters on which emission are measured such as HC, CO and smoke were larger in dual fuel type operation whereas in pure diesel these emissions are less.

2.3. Brenneisen et al [3]
Find 33.6% saving of fuel. On comparison of diesel fuel mode and dual fuel engine that is running at 1200 rpm it is founded that thermal efficiency increases from 31.92% to 34.85% and for 1400 rpm it is 31.03% to 35.60%. Temperature of gas at Exhaust is proportional to speed of the engine if the flow rate increases from 76 lpm to 125 lpm. The exhaust gas temperature also enhance from 17.99% to 46.03% with 1600 rpm. There is increment in smoke opacity from 4 to 6.07Km⁻¹ with enhance the flow rate. The CO emission increased from 0.62% to 1.69% by volume at increasing flow rate from 76 lpm to 125 lpm due to sufficient oxygen it is founded that at 1600 rpm the CO level are minimum. Similarly HC emission also increases with increase in flow rate.

2.4. Jesper Ahrenfeldt et al. 2004 [4]
Describes the emission of CO is the degree of measurement of incomplete combustion of hydrocarbon and an indicator of PAH (poly nuclear aromatic hydrocarbon). This emission is due to less of oxidizer, pyrolysis of hydrocarbon results in PAH, which happens due to lack of oxygen. If temperature in boiler is high then PAH may decompose. Emission of CO from engine using producer gas is unlike the natural gas engine.CO emission are restricted by air-fuel ratio. It is characterized by the factor λ, which is the ratio of air-fuel (actual) and air-fuel ratio (stoichiometric) .For natural gas (λ<1.2), CO emission decreases due to partial oxidation of hydrocarbon if λ increases then CO emission also increases and for producer gas CO emission are higher essentially at λ>1.5.

Factors for PAH emissions are organic aerosol, higher hydrocarbon in fuel gas, engine lubricant when mixture is fuel rich that is λ<1. The hydrocarbons doesn’t oxidize completely but get pyrolysis and results in formation of tar and PAH. PAH is also formed due to fuel trapped in cervices of the combustion chamber.
2.5. D.K. das et al. [5]
Describes that using gaseous fuel is founded as more advantageous because this given better efficiency, rate of release of heat is more, energy output can be controlled and managed. Producer gas needs 2.5-3 kg wood to make equal amount of energy as 1L of diesel. A downdraught type of gasifier was designed for 10.7 Nm³/h with maximum load of 0.9 N-m³ (cm³-h). The diesel engine was analyzed on various load for 5 minutes each. Parameter were measured, the data is used to find thermal efficiency and specific diesel consumption in engine. The performance is evaluated with the help of above parameter. The thermal efficiency increased from 28% to 31% with increase in biomass moisture by 8% to 21%. The percentage of efficiency varies from material to material. The efficiency is much better with wood chips and corn cobs as compared to diesel mode and combustion is better with wood chips and corn cobs than pea stalks pigeon but energy content in pigeon pea stalk is high. There is 60%-64% less energy consumption for dual mode as compared to diesel mode.

2.6. Carlo Caligui and Massmiliano Renzi [6]
Analyzed the engine thermodynamically for sake of renewable sources, alternative methods were analyzed that results in introduction of producer in scenario. Although its quality is not satisfactory as compared to natural gas and gasoline still it is beneficial to environment as it is ecofriendly. SI engine needs modification to work with producer gas depends on ignition time, compression ratio of the engine and engine’s rotational speed. Ignition time should be exceed by 30-40 degree with the help of low flame speed for CI engine de-rating is less than 30 percent for diesel engine by producer gas. So dual fuel engine comes in strategy. Dual fuel mode proves to be beneficial because of smooth operation with less noise. It is also economically fit and emission levels are very low. The analysis is done on thermodynamics’ first law that is conservation of energy. More researches are done further on this topic.

2.7. G Sridhar et al. [7]
Worked on a open top reburn downdraft type of biomass gasifier which is beneficial for gasification purpose to produce less tar content gas, has a feasible calorific value [18,19]. The calorific value is about 5.2 ± 0.2 MJ/Nm³ and there is a necessity of 1.2 to 1.4Kg of air which is needed for per Kg producer gas [17]. The analysis is done on dual fuel mode in CI engine. About 20-30% of power can be lost when alone producer gas was used in the operation but the power can be compensated as toxic gases was generate in very less amount. NOx level is founded low in this as compared with diesel on the basis of lower peak flame temperature, but CO levels are more because of incomplete combustion. If we use producer gas only in SI engine the level of CO and NOx is founded less.

2.8. Vinay shrivastava et al. [8]
Describe that to design a downdraft type of gasifier was developed to running for 4-stroke, single cylinder. At different gas flow rates engine emission and performance characteristics were studies at various loads. In comparison the dual fuel type engine, brake thermal efficiency of diesel engine is more. Highest efficiency for diesel engine carryout was 21.5% whereas highest efficiency in dual fuel was 26%, 24.5%, & 25% for D+PG 4lpm, D+PG 6lpm & D+PG 9lpm respectively. At entire loading condition the specific energy consumption of diesel engine mode is constantly lower than that of dual fuel and the temperature of Exhaust Gas for diesel fuel mode is constantly less than dual fuel, this is because to provide extra energy to the engine . HC, CO, NOX exhaust are found that low compare to dual engine.

2.9. Felipe Centeno et al. [9]
Describe the performance on a model to check and developed the performance in a steady state of a downdraft type gasifier of biomass & spark ignition engine power system. In this paper they was used
fixed bed type downdraft gasifier & IC engine of SI. The gasifier, divided into three parts for the calculation, namely pyrolysis, drying, oxidation and reduction sections. And further arithmetical model of gasifier consisting, three different sub-models, each processes describing the corresponding zone. And after further numerical results was obtained. Due to numerical results they get better overall efficiency in “biomass-to-energy” process of conversion.

2.10. S.Ramadhas, S.Jayaraj, C.Muraleedharan [10]
Describe the analysis of gasifier in this coir and wood chips used as the input. To study the work of gasifier and engine system, so engine is moving on various load and producer gas air flow ratios. At various loading condition engine with diesel are compared with that of dual fuel based engine on accounts of work and emission characteristics. After the performance we found that brake thermal efficiency of engine with diesel is more than dual engine. And in diesel mode the peak brake thermal efficiency is 25% was achieved. And in the operation in dual fuel mode, the maximal brake thermal efficiency are 21% at 70% of load with the use of wood chips and 19.9% at 70% load with coir-pith. The sp. energy consumption of diesel fuel mode is lower than dual mode at every loading conditions. In dual mode, there is decrease in the performance of engine with diesel or with rubber-seed oil acting as the pilot fuel. The amount of carbon monoxide emissions are higher with rubber seed oil-producer as compared to operation with diesel-producer gas below every loading conditions due to more consumption of fuel with less calorific value fuels. And it is also found that the amount of CO2 is higher in rubber oil-producer gas. At last, it is found that power generation cost is cheaper while using biomass as compared to the conventional power generation cost.

2.11. N.R. Banapurmath et al. [11]
Studied on honge oil and its methyl ester. Engine with dual fuel is used. To compare and evaluate the work of injection in CI engine which is connected with and without gas carburettor on dual fuel mode, to know the famous various other fuels like honge oil etc. Producer gas is the total alternative of fossil fuels. To find Hounge oil methyl ester, so Tran’s esterification is used to reduce the viscosity of Hounge oil (Pongamia Pinnata Linn) which is to be selected according to the previous performance. We know the higher smoke emissions are produce by vegetable oils, so to improve their performance we adopted the dual fuel operation. Different values of brake thermal efficiency was obtained 23%, 22.25% and 24.25% with producer gas-Honge oil with methyl ester, producer gas with onl honge oil and producer gas-diesel, respectively. Emission such as NOx and smoke was reduce considerably in dual fuel operation. However, CO and HC emissions increased significantly.

2.12. Mohammad Asadullah [12]
Describe that one of the promising technologies is gasification is used to transform biomass into gaseous fuels energy generation. In this paper, they highlighted the biomass to electricity generation by removing the barrier in each and every steps. In this review, they discussed the effect of pre-treatment and parameters used in supply chain management, and refining and usability of gas for energy generation. According to previous paper, the improvement in method of gasification with effectively tar removing can efficiently elimination the consumption of biomass, and the biomass and logistics pre-treatment issues can be significantly reduced. With the help of small size (1-10MW) of the plant we can reduce the technical problems. Higher thermal efficiency is achieved due to combined agent of gasification, for instance, steam and air, was provided desirable gas composition for the engine.

2.13. P.Raman et al. [13]
Studied on to produce a clean gas to design a downdraft gasifier-dual system, used for electricity generation. With the the help of this system we improve a number of technical challenges. Indirect cooling of gas and dry gas purifying equipment is equipped with this system. Due to enhanced gasifier performance, the amount of tar present in the raw gas is not more than 100mgNm-3. Gasifier-dual
system produces the very lower tar content, are 67mgNm-3 against 711mgNm-3 of the reactor. So, low dust content gas is produce with improved system, are 53mgNm-3 against 1360mgNm-3 at the end of the reactor. Level of tar content is 35mgNm-3 at the end of the gas purifying train. Gas calorific value is 5.3MJNm-3. Fuel wood/kg a producer gas of specific gasification rate is 2.8Nm-3. The normal value of fuel consumption is 1.5-1.6 Kg kWh-1 against the 1.1 kg fuel wood/kWh. Efficiency of an electric transformation of the biomass system is noticed to be 21%.

3. Performance parameter:

3.1. Brake thermal efficiency:
The energy in brake power per unit input energy is known as brake thermal efficiency.

Brake thermal efficiency get increased by 4% by the use of producer gas. The above figures indicates the variability of brake thermal efficiency along with the brake power for different types of fuels. The curve of rice husk is varying same as the air + diesel curve up to 1kW brake power bur after that there is increase in brake thermal efficiency of the fuel with rice husk. Similarly, fuel with eucalyptus have same efficiency as wood chip’s fuel but the efficiency of eucalyptus based fuel is increased after 1kW of brake power. In this way the above curves shows the variability of efficiency at different value of brake power.

3.2. Exhaust gas temperature
It is the indication of how energy is converted in work.it is founded higher in leaner mixture. If the exhaust gas temperature is higher than NOx level also increases.
The above indicates the variability of exhaust gas temperature along with the brake power on various types of mixtures of fuels.

3.3. Brake specific energy consumption
It is termed as the fuel consumed/brake power.

In the above fig. it is shown that how the Brake Specific Energy Consumption changes at different value of brake power for different types of fuels such as Air+Diesel, Air+Diesel+producer gas(wood chips), Air+Diesel+producer gas(Bagasse) & Air+Diesel+producer gas (Rice husk). In which rice husk based shows better results than other fuel.

4. Conclusions
From the above paper various things are concluded that for CR17:1 overall efficiency for 17.5kW is 21% and for 21kW this is found to be 31%. With 1200rpm, diesel mode and dual fuel mode engine gives 3% increment in thermal efficiency and for 1400rpm, it is increased by 4%. If we increased flow rate then emission of CO and HC is also increased but by providing sufficient oxygen, CO emission can be reduced. Producer gas needs 2-3kg to give equal amount of energy as 1L diesel. Flow rate also enhance the saving of fuel.
5. References

[1] G. Sridhar, P.J. Paul, H.S. Mukunda. Biomass derived producer gas as a reciprocating engine fuel- an experimental analysis, 2001.
[2] Praveen Pandey. Energy and Emission analysis of dual fuel CI Engine Using Diesel and Biomass Derived Producer Gas, March 2010.
[3] S.Dasappa & H.V. Sridhar. Performance of a diesel engine in a dual fuel mode producer gas for electricity power generation. 20 Sep 2011.
[4] Jesper Ahrenfeldt, Torben Kvist Jensen, Ulrik Henriksen , Jesper Schramm and Benny Gobel, CO Emission from Gas Engine Operating on Biomass Producer Gas, 2004.
[5] D. K. Das, S. P. Dash, M. K. Ghosal, Performance evaluation of a diesel engine by using producer gas from some under-utilized biomass on dual-fuel mode of diesel cum producer gas, 2012.
[6] Carlo Caligiuri, Massimiliano Renzi, Combustion modelling of a dual fuel diesel – producer gas Compression ignition engine, August 2017.
[7] G Sridhar, S Dasappa, H V Sridhar, P J Paul, N K S Rajan, Gaseous Emissions Using Producer Gas as Fuel in Reciprocating Engines, April 2005
[8] Vinay shrivastava —design and development of downdraft gasifier for operating ci engine on dual fuel model department of mechanical engineering National institute of technology Rourkela may 2012 1-78
[9] Felipe Centeno, Khamid Mahkamov, Electro E. Silva Lora, Rubenildo V. Andrade —Theoretical and experimental investigations of a downdraft biomass gasifier - spark ignition engine power system Renewable Energy 37 (2012) 97-108
[10] A.S. Ramadha , S. Jayaraj, C. Muraleedharan —Power generation using coir-pith and wood derived Producer gas in diesel engines! Fuel Processing Technology 87 (2006) 849–853
[11] N.R. Banapurmath, P.G. Tewari —Comparative performance studies of a 4-stroke CI engine operated on dual fuel mode with producer gas and Honge oil and its methyl ester (HOME) with and without carburetor! Renewable Energy 34 (2009) 1009–1015
[12] Mohammad Asadullah —Barriers of commercial power regeneration using biomass gasification gasl Renewable and Sustainable Energy Reviews 29(2014)201-215
[13] P. Raman, N.K. Ram, Ruchi Gupta —A dual fired downdraft gasifier system to produce cleaner gas for power generation! Energy 54 (2013) 302 to 314
[14] Rohan R. Patel, DR. Rajesh C. Iyer, Hiren Mahida & Nirmalkumar, A Review paper on Theoretical & Experimental Investigation of a Dedicated Producer Gas Engine Technology, 2015.
[15] Mahida Hirenkumar Ranjitsinh, Rajesh C. Iyer, A Techniacl Review of Producer Gas as an Alternative Fuel for Internal combustion Engine, 1 January 2015.
[16] Heywood John B., (1989), Internal Combustion Engine Fundamentals, International Edition, McGraw-Hill, New York, pp. 572-589.
[17] 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.
[18] Ramachandran A. (1993) Performance studies on a wood gas run IC engine, Proceedings of Fourth National Meet on Biomass Gasification and Combustion, Mysore, India Vol 4, PP 213-218.
[19] Francisco V. Tinaut, Andres Melgar, Alfonso Horrilo, Ana Diez de la Rosa (2006): Methods of predicting the performance of an internal combustion engine fuelled by producer gas and other low heating value gas, Fuel Processing Technology 87, PP 135-142.
[20] J. P. Yadav, Performance Analysis of Producer Gas Based Diesel Engine, Volume 2, Issue 1, and ISSN: 2277 – 5668