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Performance of a Gas Run Petrol Engine for Small Scale Power Generation

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Abstract

The use of domestic line supply of natural gas as an alternative fuel in a 1.5 kW portable electric generator was studied. In order to retain instant interchangeability to petrol fuel and minimum alteration cost, the engine modifications were kept to a minimum. The engine running with natural gas showed improved performance regarding - fuel economy, overall efficiency and significantly better exhaust emission characteristics, compared to the petrol counterpart. Output power was reduced 10~15% and the gas flow-controlling requirement introduced some added complexity. Taking the economical and environmental benefits into account, natural gas could be a very potential alternative fuel for small-scale power generation using SI engines.

Introduction

The ever-increasing energy demand is now a prime concern of the whole world. The limited resources of conventional fossil fuel will not be sufficient for meeting the energy demand of very near future. Therefore, search for possible alternative fuel is being tried in both developed and developing countries. The issue of environmental pollution created by conventional fossil fuel is becoming more important, as we are getting more concern about the environment of our planet. These concerns as well as emission standards enforced by legislation, have led the research for the use of alternative fuels in different prime movers, including the extensively used internal combustion engines.

Fuels, which have been studied for replacing petrol include - natural gas, compressed natural gas (CNG), liquefied petroleum gas (LPG), hydrogen, bio-gas etc [6]. Each of these has its merits and demerits in respect of its use for the specific application. Among these alternative fuels, natural gas is the one attracting significant attention at present time. Pollution level from the engine could be drastically reduced using natural gas [8]. Unlike liquid petroleum reserves, natural gas is widely distributed around the world with substantially large reserves already discovered in most of the regions [7]. Although the use of other alternative fuels may be more convenient, advantageous or feasible from different points of view, at the present time, the availability of natural gas, relative simplicity of engine conversion technology, economical and environmental benefits and in some cases strategic advantages make it the preferred fuel [3].

Bangladesh is facing ever increasing pollution problem and also trying to meet the power demand of her vast population. Therefore, small-scale power generators are being widely used to cope up with the frequent power failures. An investigation regarding the operation of these generators with the domestic line supply of natural gas, with minimum engine modification may be very useful at the present context.

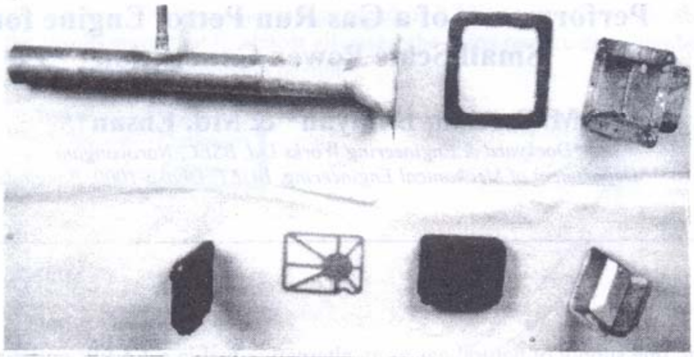

Fig. 1. Modification in the air -intake structure , original components of petrol run engine (at the bottom) and the modified version for running with natural gas (at the top)

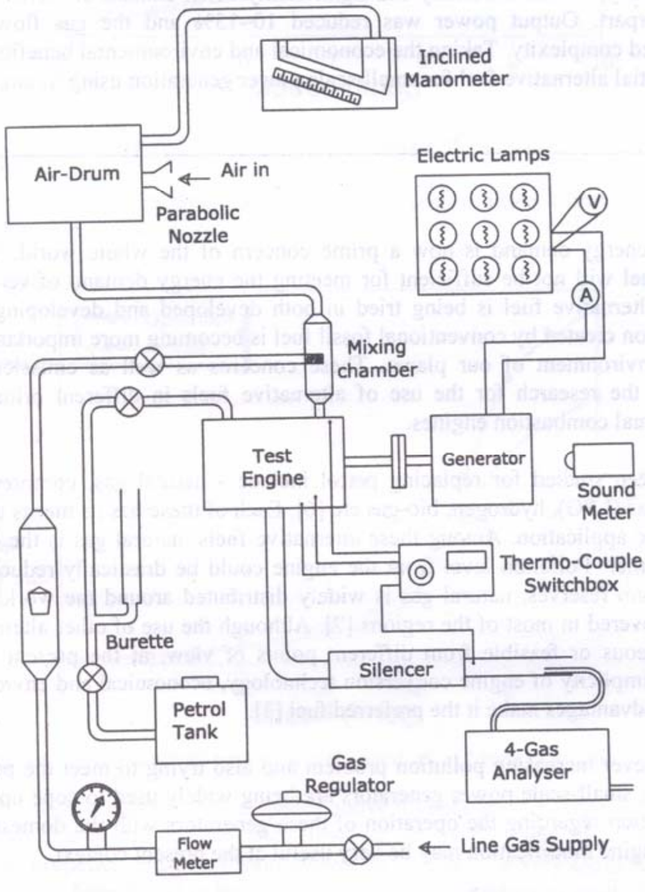

Fig. 2. Schematic diagram of the experimental set-up

Instrumentation

The KUBOTA engine-generator set (AE2400LX) used for test purpose consisted of a - 200cc, single cylinder, 4-stroke, air-cooled SI engine directly coupled with a generator of rated output capacity of 1.5 kW, 220V, 50Hz electricity. Several incandescent lamps mounted parallely on a panel board was used as variable electric loads.

Although the engine was designed for running on petrol, it was adopted to run on domestic line supply of natural gas during part of this study. It was desired to run the engine on natural gas with minimum modification to the hardware and retaining the capability of switching back to its petrol fueling system easily. For this simple modification in the air intake structure incorporating an external mixing chamber was designed. The mixing chamber used for test purpose was of cross flow type [1], where part of the original air intake of the engine was replaced by a modified one. The two intake structures are shown in figure-1.

Petrol and natural gas flow were measured volumetrically, using burette and flow meter respectively. The air flow rate was measured by allowing the air to pass through an air drum mounted with an small parabolic nozzle at its entrance and taking the vacuum pressure reading of the nozzle exit point with an inclined manometer [5]. The natural gas flow, that was used for test purpose was of regulated domestic line supply (0.01 bar gauge).

Exhaust gas was analyzed using a 4-gas emission analyzer (CRYPTON 290). The percentage of oxygen (O_2), carbon-di-oxide, (CO_2) and carbon-monoxide(CO), total hydrocarbon (HC) in ppm, equivalent ratio of the intake air-fuel mixture and the engine speed was measured using the analyzer for both the fuels. Figure-2 shows the schematic presentation of the entire experimental setup.

Performance characteristics and discussion

The variation of - air flow rate, fuel flow rate, air-fuel ratio, brake specific fuel consumption, overall efficiency, percentage of exhaust emission components with a range of electrical loading (up to the rated value of 15 kW) were the main parameters studied, with the engine running on petrol as well as natural gas.

The air flow rate, while using natural gas was found to be slightly lower (4.8 kg/hr) than that of petrol (6 kg/hr) at no load condition as shown in figure-3(a). The increment of air flow rate with load was almost linear for both the fuel although having slightly different slopes, reaching similar values near the rated load. As relatively greater volume was occupied by the natural gas in the intake charge [9], the air flow rate was found to be around 85~90% of that of petrol. The variation of fuel flow rate with load for both the fuels were almost linear. For petrol, it was found to vary from 0.6 kg/hr to 1.0 kg/hr and from 0.3 kg/hr to 0.54 kg/hr at full load condition, with natural gas as shown in figure-3(b). Different gravimetric heating values of the two fuels mainly causes this difference. Consequently the value of air-fuel ratio was found to be different for the two fuels. This was found to be almost near 10 for petrol throughout the range. This indicates the richness of the mixture, because the stoicheometric A/F ratio for petrol is around 14.8. While using natural gas, the air-fuel ratio varied within a range form 15 to 21 with load variation (stoichiometric ratio about 17.2). This variation may be attributed from the manual adjustment of the suitable gas flow control at different loads. In addition to calculation from air and fuel flow rates the AF-ratio was also measured from the exhaust gas analyzer and both the curves were found to be in close agreement as shown in figure-3(c).

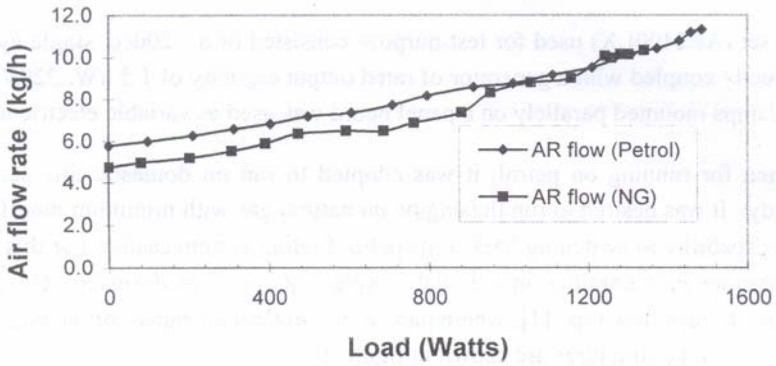

Fig. 3(a) Variation of air flow rate with load

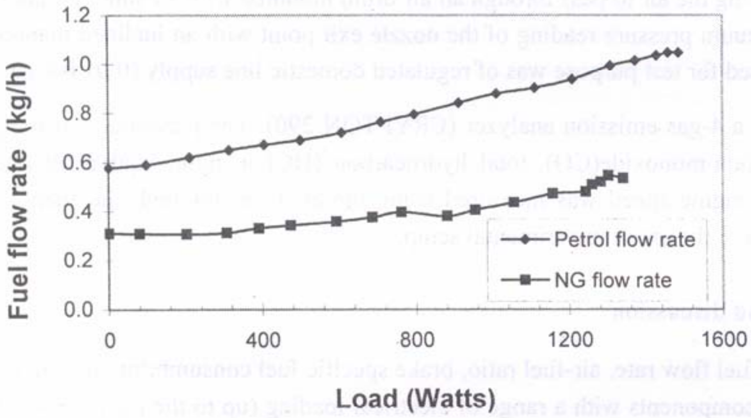

Fig. 3(b) Variation of fuel flow rate with load

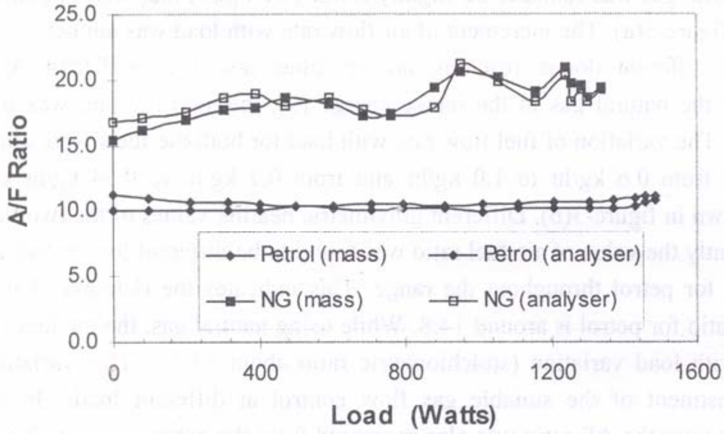

Fig. 3(c) Variation of air fuel ratio with load

The brake specific fuel consumption (bsfc) of the engine for both the fuels were found to be very high at low loads, decreased sharply with load and remained steady at higher load region which is shown in figure 4(a). The bsfc of the engine for fuel, petrol was around 3 kg/kW-h with 200W load and fell to below 1 kg/kW-h after 800W and then changed gently to around 0.7 kg/kW-h up to the rated load. For natural gas the bsfc was found to be 1.5 kg/kW-h at 200W load and decreases sharply with load and after 500W it reached to an almost constant rate of 500 g/kW-h. As the different fuels have different heating value, the lower values of bsfc does not necessarily indicates the better performance. The comparative performance of the two fuels could be studied by comparing the overall efficiency curves shown in figure-4(b). As electric power finally produced was of our main concern, overall efficiency was defined as the ratio of output electric power consumed by the load to the heat input of fuel.

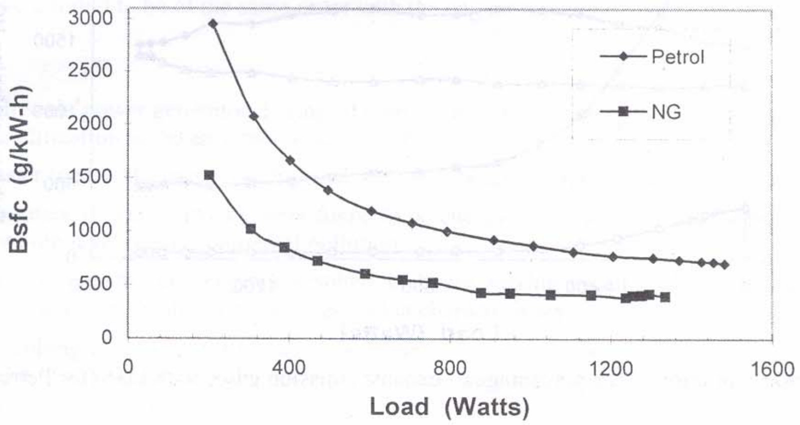

Fig. 4(a) Variation of bsfc with load

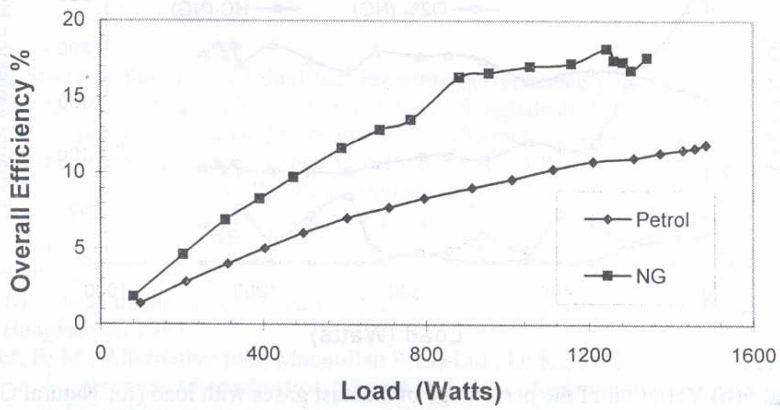

Fig. 4(b) Variation of overall efficiency with load

The overall efficiency was found to improve to 16% at rated load with natural gas, compared to around 12% with petrol. This apparent improvement in overall efficiency has more to do with complete combustion of fuel [2], rather than real enhancement of efficiency using natural gas. The higher air flow rate for petrol indicates that, improper mixing rather than lack of air, most probably is the main cause of its higher fuel consumption rate. The improvement in bsfc while using natural gas is the most important for Bangladesh from economic aspects where the cost of petrol is about 6~10 times more than that of natural gas [4]. The engine was found to be capable of producing nearly 85% of the rated capacity while running on natural gas. This is because, the reduction of air flow rate limits the maximum power output in spite of the better combustion [7]. Improper spark advance relating to slower flame propagation speed may also contributes to this [5]. Beyond the 85% of the rated capacity, the engine performance running on natural gas was found to be deteriorating.

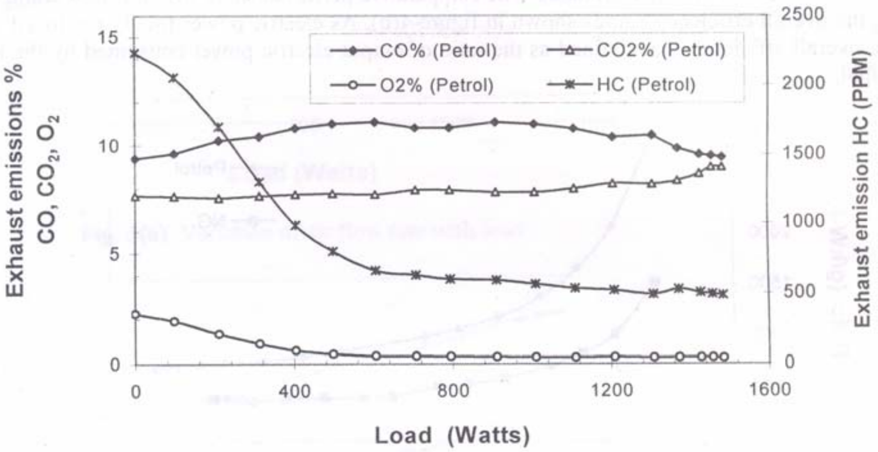

Fig. 5(a) Variation of the percentage of exhaust emission gases with load (for Petrol)

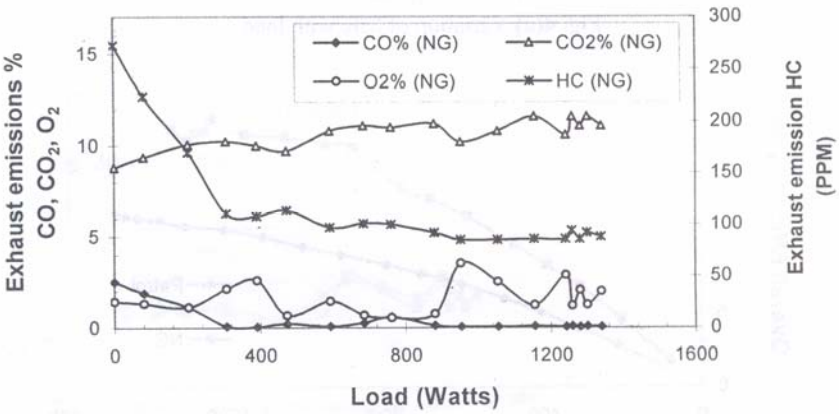

Fig. 5(b) Variation of the percentage of exhaust gases with load (for Natural Gas)

The percentage of emission gases (3 gases) for both the fuels were studied. CO, CO_2 and O_2 percentage in emission gas were found to be different for these two fuels and improving significantly for natural gas. It was found that, the percentage of CO for petrol was almost same (around 10) throughout the loading range. At the same time the percentage of CO_2 and O_2 were also found to remain almost unchanged with load. These values were around 8% and 0.3% respectively. The percentage of O_2 was a little higher at lower load (1~2%). The amount of hydrocarbon (HC) measured in ppm was found to be very high (more than 2000) at no load or lower load and decreased sharply with increment of load and after a certain loading condition, (above 500W) this value becomes steady at 500ppm. While using natural gas, the percentage of CO was found to be very low. At no load or very lower load, this value was around 2% and drastically fell to below 1% after applying 250W load and then becomes around 0.07% at higher load. The percentage of CO_2 was found to be more than that of petrol. It was also almost same throughout the whole loading condition and was varied from 9~11%. The percentage of O_2 was found low but greater than that of petrol. The variation was not smooth but fluctuating between 1~3% throughout the whole loading condition. HC was found to be around 250ppm at no load or lower load and fell sharply to around 100ppm after 400W. Fig. 5(a) & 5(b) shows the variation of the percentage of emission gases with load for both the fuels.

Measurements of temperatures at different engine locations revealed about 5-10% increase of body temperature while using natural gas. Variation of engine speed was found to be very small for both fuels. Measurements of sound level were found to be of the same order with the engine running on petrol or natural gas.

Conclusions

- The small scale power generator driving SI engine could be run on domestic line supply of natural gas with simple modification at the air intake system of the engine.
- It was easier to start the engine with petrol and then switching over to natural gas fuelling system.
- The SI engines of small capacity were found to be energy inefficient devices for power generation, causing relatively high level of environmental pollution.
- Using natural gas in such engines resulted in better mixing of air and fuel leading to more complete combustion and significantly improved emission characteristics.
- Though running more efficiently, the power output decreased about 15%, compared to the rated capacity with petrol. The system also demanded additional flow regulation to control the gas flow with varying electric loads.
- The performance of the engine generator set using natural gas could be improved further using more hardware modifications, but a socio-economic feasibility study would be necessary for its justification.

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