



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Optimal Operating Parameters for Performance Improvement of a Biogas Fueled Spark Ignition Engine

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SHORT ABSTRACT

The environmental concerns and the uncertainties associated with the future availability of fossil fuel are driving the interest of utilizing renewable biofuels in the internal combustion (IC) engines. Among the renewable gaseous fuels, biogas is an attractive source of energy in rural areas and is mainly composed of CH₄ (50-70%), CO₂ (25-50%), H₂ (1-5%), N₂ (0.3-3%) with traces of H₂S. Direct use of biogas as a standalone fuel in CI engine is almost impossible due its properties such as higher self-ignition temperature, higher resistance to auto ignition and knock. But, the physical and chemical characteristics of biogas have a great resemblance on the octane fuels in higher compression ratio (CR) SI engines. Although SI engines are best suitable for renewable or non-renewable high-octane fuels, they need special attention to accommodate biogas. The combustion process in a SI engine is greatly influenced by the operating parameters. Various techniques such as alteration in CR and IT, preheating, pre-chamber ignition, etc. were proposed to enhance the performance, combustion and emission characteristics of the biogas fueled SI engine. Thus, one of such techniques, with proper optimization of operational parameters, can be employed to develop an efficient biogas-based SI engine. The current research is mainly focused to determine the optimal operating parameters (optimum compression ratio, maximum brake torque timing, throttle position and optimum air-fuel ratio) of a biogas fueled SI engine through a multi fuel, variable compression ratio (VCR), spark ignited research engine setup for effective implementation in a commercial SI engine.

The preliminary investigation of the study was started with a commercially customized biogas fueled constant speed SI engine (Engine 1) of rated capacity 4.4 kW. The rated power, speed, CR and IT of the engine were 4.4 kW, 1500 rpm, 13.94:1 and 15.88° CA bTDC, respectively. The engine was

assessed under dynamic loading condition. Operating the engine at the rated CR (13.94) and maximum brake load condition (74.8%) declines the rated speed of the engine by 9.3% and deteriorate the engine power by 34.5%. The maximum achievable BP and BTE of the commercial biogas engine was observed 2.9 kW and 14.4%, respectively at the rated CR. The issues and inefficiency identified with customized commercial biogas engine (Engine1) motivated to explore the possible techniques to convert and optimize the efficiency of the existing SI engines for biogas application. Hence, further in this investigation a variable speed VCR SI engine (Engine 2) of rated capacity 4.5 kW (at 1800 rpm and CR10) has been retrofitted with a specially designed biogas induction, VCR and VIT mechanism to operate the engine with a wide range of CR, IT, N and ER combination. Further to determine the near optimal operating parameters (CR, IT, Throttle position and ER) of the biogas operated VCR SI research engine, the investigation was planned in three stages. from 23° to 55° CA bTDC for each operating CR and engine speed configuration while the operating ER is maintained constant ($\phi = 0.79\sim 0.80$). The CR and engine speed are progressively varied from CR 8 to CR 14 and 1400 to 1700 rpm, respectively. Based on the overall performance of the biogas fueled engine, the optimum ITs are identified for each operative CR and speed range of the engine. Similarly, at the 2nd stage of investigation, the influence of the operating CR over the speed range of the engine is analyzed with the respective MBTs. The CR is progressively advanced from CR 8 to CR 14 for each operating speed of the engine by retaining the ER almost constant ($\phi = 0.80\sim 0.83$). The optimum CR is identified over the operating speed range of the engine based on the overall performance of the engine. The MBT timings of biogas fueled engine are reported 53°CA, 49°CA, 45°CA, 39°CA, 33°CA, 29°CA and 25°CA bTDC, respectively at CR 08, 09, 10, 11,12, 13, and 14. The optimum CR was reported CR 12. The maximum BP, BTE of the engine with the optimum CR and IT configuration was reported 3.5 kW and 30.3%, respectively. Further, at the 3rd stage of the investigation, the influence of operating ER (ϕ) over the operating speed range of the engine is identified for the optimum CR and IT setting of the engine. The ER is progressively varied from 0.744 to 1.109 (A/F ratio: 5.11 to 7.16) over the operating speed range for the optimum CR and IT configuration. Based on the overall performance, the optimum ER is identified and reported 0.92.

Further, in the process of developing a biogas fueled SI engine, the optimized operating parameters (CR, IT, TP and ER) attained through series of experiments in Engine 2 were incorporated in a commercial SI engine (Engine 3; Make: Honda, GX 200). The maximum achievable BT and BP of the engine were reported 11.97 N-m and 2.94 kW, respectively at 2347 rpm and WOT condition of the engine. Due to biogas mode operation, the rated power of the engine (Engine 3) was also derated and dropped by 20.54%. The average fuel consumption of the engine was estimated as 2.05 kg/h (1.84 m³/h) and 1.16 kg/h (1.04 m³/h) at WOT and PT operating conditions, respectively. The maximum achievable BTE of the engine was found 30.37% at 2347 rpm at WOT condition.