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Production and utilization of renewable and sustainable gaseous fuel for power generation applications: A review of literature

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ABSTRACT

Alternative fuels have numerous advantages compared to fossil fuels as they are renewable and biodegradable besides providing energy security and foreign exchange saving addressing environmental concerns, and socio-economic issues as well. Therefore renewable fuels can be predominantly used as fuel for transportation and power generation applications. In view of this exhaustive experiments on the use of producer gas for both spark ignition (SI) and compression ignition (CI) engine applications for short and long term trial runs have been reported in the literature. Today, the use of biomass derived producer gas is more reliant for addressing rural power generation and is a promising technique for controlling both NO_x and soot emission levels. Researchers have found that, the brake thermal efficiency of producer gas operated single and dual-fuel engines were far lower compared to diesel/biodiesel operated engine and suggested that, this can be improved by improving the fuel properties, adopting good operating parameters or altering engine design. In order to address this, many researchers/scientists have proposed different solutions for enhancing the performance of a producer gas operated engine.

Majority of the research work is focused on the utilization of compressed natural gas (CNG) and liquefied petroleum gas (LPG) in engines operated on both single and dual fuel mode. However, use of producer gas in engines still needs more detailed studies, as this area is less investigated. Literature review suggests that the combustion characteristics of the producer gas operated engines need extensive research for a long-term use in both gas and dual-fuel engine. In this context, this paper mainly presents a literature review based on the utilization of producer gas as fuel for transport and power generation applications. Based on the review of literatures, it can be concluded that this area requires more research with long term engine operation.

Contents

1. Introduction . . . 609
2. Renewable energy in India: current status, challenges and opportunities . . . 609
3. Use of producer gas for an engine application . . . 610
4. Gasifier system . . . 611
5. Producer gas with respect to production and its properties . . . 613
6. Performance, combustion and emission characteristics . . . 615
   6.1. Performance characteristics . . . 616
      6.1.1. Brake thermal efficiency . . . 616
      6.1.2. Exhaust gas temperature . . . 618
      6.1.3. Specific energy consumption: . . . 618
   6.2. Emission characteristics . . . 619
      6.2.1. Smoke opacity . . . 619
      6.2.2. Hydrocarbon (HC) and carbon monoxide (CO) emissions . . . 619
      6.2.3. Nitric oxide emission . . . 620

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1364-0321/

6.3. Fuel substitution . . . 621
6.4. Combustion characteristics . . . 622
7. Economics of biomass gasification based power generation projects . . . 623
8. Conclusions . . . 624
References . . . 625

1. Introduction

Growing population around the world needs better quality of life. In the present energy scenario, demand for energy is on a continual increase. Environmental concerns and depletion of fossil fuel reserves have led to the extensive search for alternate fuels. Using biomass as a source of energy can not only reduce the dependency on imported oil, but may also benefit the environment by reducing emissions of greenhouse gases and pollutants that affect the air quality [1–9]. Biodiesels derived from vegetable oils present a very promising alternative to diesel oil since biodiesels have numerous advantages compared to fossil fuels [1–16].

Producer gas obtained by partial combustion of biomass in a gasifier can act as a promising renewable and alternative fuel for both SI and CI engine application. Most current dual-fuel engines are made to operate interchangeably, either on gaseous fuels with liquid pilot ignition or wholly on liquid fuel injection as a diesel engine. Accordingly, a dual-fuel engine tends to retain most of the positive features of diesel operation [17]. Diesel engines cannot be operated on producer gas alone without injection of a small quantity of liquid fuel because producer gas properties will not allow the ignition to take place in a diesel engine. Therefore, a diesel engine needs to be dual fueled. Quality of producer gas affects the performance of an engine. Therefore, cooling and cleaning of gas is essential to improve the quality producer gas. The composition of producer gas depends on the biomass feed stock and gasification conditions in the gasifier. These variables have a considerable effect on gas engine performance. It is difficult to reduce (nitric oxide) NO_x and smoke simultaneously due to trade off curve between NO_x and smoke emissions. One prospective method to solve this problem is to use oxygenated renewable fuels in a dual fuel engine. It reveals that 'dual fuel concept' is a promising technique for controlling both NO_x and soot emissions even on existing diesel engine [10]. However it increases HC and CO emissions. The higher CO content in the exhaust suggests that dual-fueling should not be carried out below a certain minimum load. Researchers have reported that up to 70–90% liquid fuel saving can be obtained in a dual fueled engine [17–18].

Experimental investigations on the performance, combustion and emission characteristics of SI engine with 100% producer gas alone have been reported [12–15]. Diesel engine operated on dual fuel mode using raw vegetable oil and its methyl esters and gaseous fuel induction has been also investigated [17–23]. These gaseous fuels include producer gas, LPG, CNG, biogas, and hydrogen. Issues addressing the use of CNG and LPG with liquid fuel injection in dual fuel mode were found maximum in published literatures with acceptable performance with lower emission levels. However, use of producer gas for short and long-term use in both gas and dual-fuel internal combustion engine (ICE) resulted in lower performance. Hence, dual fuel engine with producer gas induction still needs more detailed studies, as it is less investigated. Hence, in the present work, an attempt has been made to review the literatures based on the utilization of renewable gaseous fuel (producer gas) in both spark ignition (SI) engine called as gas engine and compression ignition (CI) engine using liquid fuel as injected fuels.

2. Renewable energy in India: current status, challenges and opportunities

Demand and supply, untapped potential, air pollution and environmental concern are the key drivers for renewable energy. Many villages still do not have any electricity. Per capita electricity consumption is 733 units and world average is 2596 units as per 2005 data. However, India has already installed 150,000 MW generating capacity from renewable energy and is moving towards decentralized power generation on a large scale for rural electrification. Biomass fuels in various forms are abundantly available in most of the countries. Comparing to more advanced countries, the biomass scenario in India is completely different. The GDP of India still depends on agricultural sectors; therefore huge amount of agricultural residue is available in India. It has been estimated that India has a surplus of about 120–160 million ton of agricultural residues every year. India currently has total installed capacity of 147,000 MW of which 81,859 MW (66.30%) comes from thermal power plants based on coal, gas and oil. The percentage share of renewable is 6158 MW (5%) of the total. India has a potential of the order of 19,500 MW which includes around 3500 MW of surplus power from bagasse-based co-generation, and 16,000 MW of grid power from biomass material. India has about 140 million ha of land not used productively. Already, energy plantation of about 40 million ha was done. It can fuel about 17,000 biomass gasifiers of 10 kW each. Through which about 300 MW conventional power plant capacities can be replaced [23]. Use of renewable and alternative fuels for internal combustion (IC) engines is necessary due to uncertainties associated with the future availability of fossil fuel. Biomass-based decentralized energy generation technologies offer an attractive solution to the energy crisis. One feature of renewable and alternative sources of energy is that they are well suited for developing decentralized power plants to meet the energy needs of rural and remote areas.

Bio-derived gas and liquids appear more attractive in view of their friendly environmental nature [17]. The major challenges that face the use of biomass for engine application as fuels has been reported [23–31]. Distribution, continuous availability, transformation with respect to oil sector, optimizing the renewable energy resources, investment and capital cost are major challenges. In addition, the unstable market of biomass due to lack of fully established biomass energy conversion technology is attributed to the difficulties of the biomass collection system. The optimized collection, storage and transportation method along with suitable selection of the power plant location can significantly reduce the cost related to the biomass feedstock. However, capacity building and transaction costs play major role in the renewable energy sector. They all include logistic constraints, man power and facilities. However, it may be noted that small renewable energy projects have high transaction costs during its development.

At present, generating energy from biomass is rather expensive due to its lower conversion efficiencies, and logistic constraints. In particular, the logistics of biomass fuel supply is likely to be complex owing to the intrinsic feedstock characteristics, such as the limited period of availability and scattered geographical distribution over the territory. In this context, India has implemented many control policies towards enhanced capacities in the renewable