Abstract

Due to global population growth, energy demand has surged, especially in developing countries with dispersed rural communities. Consequently, the centralized grid system is unable to keep up with the escalating energy demand, leading to electricity shortage. Moreover, providing affordable electricity to remote areas is a challenge. Hence, decentralized power in these regions has been becoming an increasingly important issue. Power generation using fossil diesel in compression ignition engines (CI) is an old practice in remote locations of developing nations. However, the use of diesel engines leads to over exploitation of conventional fuels causing concern over environmental degradation. Hence, there is a huge demand for generating remote electricity by utilizing available renewable resources with the help of existing diesel engines. Dual fuelling of a conventional diesel engine is a mode of combustion which involves a small pilot injection of high cetane liquid fuel that ignites a pre-mixed combination of high octane gaseous fuel and air. The liquid fuel is called the pilot fuel and the gaseous fuel is called the primary fuel. The use of biofuels (liquid and gaseous form) can provide a clean alternative substitute for conventional diesel in dual fuel (DF) engines. Biogas (BG) and producer gas (PG) have emerged as a low cost renewable fuels. Both BG and PG have their own advantages and limitations to be used as a primary fuel for DF operations. Operations in DF mode individually with BG and PG exhibits inferior combustion characteristics compared to conventional diesel. However, these gases possess high anti-knocking properties and they have the potential to control the exhaust emissions. Moreover, combining these two gases might subdue each other's limitations when introduced to the DF engines. Therefore, it is important to study the performance and emission characteristics of a DF engine run on BG-PG mixtures under varying operating conditions, namely, load, compression ratio (CR) and injection timing (IT). The present contribution is focused to perform a systematic experimental analysis for a diesel engine powered by BG and PG using biodiesel-diesel blend as pilot fuel. The motivation of this present investigation is to provide a perfect competitive promotion of biodiesel-biogas-producer gas as the alternative fuel for clean energy generation for rural electrification.

First of all, a comparative experimental investigation is carried out with ten different tri-biodiesel-diesel blends to evaluate the best blend to be used as pilot fuel for DF operation. Three non-edible biodiesels namely Jatropha (JB), Karanja (KB) and Mahua (MB) are mixed with the conventional diesel fuel at 30:70 ratio to prepare tri-biodiesel-diesel blends. The tri-biodiesel-diesel blends resulted in lower brake thermal efficiency (BTE) than that of diesel fuel, while emission of carbon monoxide (CO) and hydrocarbon (HC) was found to be lower. The blended fuels with higher cetane number resulted in shorter ignition delay compared to diesel. Tri-biodiesel-diesel blend with combination of 15%JB+10%KB+5%MB, namely Blend-2 is found to be the best blend with comparable BTE of 24.65% and minimum CO and HC emission of 46.24 ppm and 22.17 ppm, respectively.

For DF experimentation, a 3.5 kW single cylinder, four-stroke, variable compression ratio diesel engine is modified to operate under DF mode connecting a novel venturi gas mixer. The primary gaseous fuels utilized for the study are simulated biogas (SBG), simulated producer gas (SPG), and SPG-SBG mixture. For the preparation of SBG, methane (CH_4) and carbon dioxide (CO_2) are mixed at four different ratios (55:45, 60:40, 65:35 and 70:30). Similarly, hydrogen (H_2) and carbon monoxide (CO) are also mixed at four different ratios (40:60, 50:50, 60:40 and 70:30) for the preparation of SPG. Again, H_2 and CO at a 50:50 ratio are mixed with a four different ratio of CH_4 and CO_2 to simulate the SPG-SBG mixture. Compared to fossil diesel with a BTE of 27.57% at standard operating condition, SBG-4 (70% CH_4 and 30% CO_2), SPG-4 (70% H_2 and 30% CO) resulted with maximum BTE of 25.1 and 25.58% at full engine load, CR of 18 and IT of 29° BTDC. At similar operating conditions, maximum PFR of 90.59 and 87.77% was achieved for SBG-4 and SPG-4, respectively. In case of SPG-SBG mixture, SG-4 (SPG-2/SPG-4) showed the maximum BTE and PFR of 24.44% and 86.41%, respectively. Moreover, NO_X emission for SPG-SBG mixture was found to be 64.2% lower than that of SPG-DF operation.

This is followed by on-field investigation of DF diesel engine run on BG and PG mixture generated from anaerobic digester and biomass gasifier, respectively. The experiments were carried out with raw BG, PG and four different BG-PG mixtures. The BG-PG mixture combinations were inducted to the engine based on controlled regulation of valve opening of BG and PG. DFM-3 i.e. 60° opening of BG valve and 30° opening of PG valve showed highest BTE and PFR i.e. 23.28% and 90.22%, respectively at full load, CR of 18 and IT of 29° BTDC. At similar condition, the BG and PG flow rate was monitored to be 2.21 and 2.51 *kg/hr,* respectively. The minimum emission of CO and HC was 267.21 and 175.31 ppm, respectively. Higher CR and advancement of IT provides supplementary benefits in terms of augmenting the engine performance and minimizing the exhaust emission. Hence, this novel technology package could be prescribed for remote decentralized power generation.

Keywords: Tri-biodiesel-diesel blend; Simulated gaseous fuels; Biogas; Producer gas; Dual fuel diesel engine; Compression ratio; Injection timing