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Performance Test on Reciprocating Engine

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ABSTRACT :

An experimental test rig has been built to test reciprocating compressors of different size and capacity. The compressors were tested with air as working fluid .The paper provides much needed information regarding the efficiency of the compressors operating under the same conditions with the same system parameters. This paper also reports on investigation carried out on the effect of pressure ratio on indicated power, isothermal efficiency of both compressors. The results show that there is increase in indicated power as the discharge pressure increases, but the isothermal efficiency of both compressors decreases with increase in pressure ratio. Both compressor types exhibit the same general characteristics with respect to system parameters. Apart from this there is no change in volumetric efficiency because the experiment was carried out for constant angular speed of compressor. In addition, a comparative study was carried out for two compressors and the observed difference swere analysed. This study was also useful to verify the model's goodness with the aim of predicting the compressor performance. Keywords: Reciprocating air compressor, volumetric efficiency and isothermal efficiency.

INTRODUCTION

Fossil fuels supply nearly 80% of world energy demand [1]. Burning of fossil fuel always has associated with it emissions in the forms of nitrogen oxides (NOX), sulfur oxides (SOX), carbon monoxide (CO), unburned hydrocarbons (UHC). These emissions have environmental impacts that are both local and global. Moreover, in recent years, air quality has become a severe problem in many countries, and the interest to replace fossil fuels with renewable and sustainable energy sources has increased for reducing CO2 and methane emissions. Landfill gas, a potential alternative energy source, is generated from anaerobic decomposition of municipal solid waste deposited in landfills. The main portion of landfill gas is mainly comprised of methane and carbon dioxide together with a smaller amount of oxygen and nitrogen and trace amounts of other gases .Methane is a highly potent greenhouse gas with a global warming effect almost 21 times greater than carbon dioxide when directly released into the atmosphere. Recently, landfill gas has attracted considerable interest as a source of alternative energy for generating heat, power

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or fuel with the benefit of reducing direct methane emission into the atmosphere, for example there have been about 450 LFGTE projects in the US [2]. However, there are some disadvantages in the use of landfill gas: composition changes considerably depending on the landfill condition, season, and the type of waste, corrosiveness, lower heating value, high maintenance issues and capital costs. Due to these disadvantages, landfill gas is sometimes not considered as a good sustainable energy resource. Hence, in order to effectively utilize the landfill gas, these problems must be adequately addressed through appropriate engineering and technological approaches. In this research, a small spark ignition engine was operated using pure methane, a simulated landfill gas, and the addition of hydrogen and carbon monoxide, and these various fuels were compared in terms of the engine performance and emissions for the purpose of assessing the efficient utilization and direct application of landfill gas.

1.1. Landfill gas

In the United States, around 340 million tons of municipal solid wastes are produced annually [3]. Among these wastes, approximately 14% is combusted for waste-to-energy, 22% is recycled, and 55% is sent to landfills [4]. Landfill gas is produced from the anaerobic decomposition of organic waste materials by bacteria following the reaction [5]: The composition of landfill gas is highly dependent on the condition of landfill sites, the atmospheric moisture in the landfill area and the type of waste used in the landfill [3]. Landfill gas is an important source not only of volatile organic compounds (VOCs) but also of potent greenhouse gases [6]. The total amount of un-captured VOCs is about 2400 tons yearly [4]. Also, landfill gas is hazardous to vent to the atmosphere because it is highly explosive. More importantly, landfill gas is the second largest source of anthropogenic methane: 7.2 billion m3 per year [4]. However, with current practices, only 60% of methane emitted from landfills is captured, the remaining 40% is emitted into the atmosphere [4]. Methane's global warming capacity is 21~23 times greater than the same volume of carbon dioxide. Because of these problems, landfill gas is flared in controlled conditions. This method prevents utilization of landfill gas as an energy source, instead the methane is converted to carbon dioxide, reducing the danger of explosion and the greenhouse effect. Rather than burning landfill gases, it is much more attractive to utilize it as a fuel to generate energy while addressing the environmental concerns at the same time.

Boiler, space heating, and industrial heating

For these applications, very little gas clean-up is required. Systems already operated on natural gas can be fueled with landfill gas with minor modification. In industrial cases, the use of landfill gas as a fuel brings financial advantages due to landfill gas systems' ability to be continuously operated for 24 hours a day, 7 days a week. Space heating applications are seasonal and require high piping costs resulting in consumers needing to live within two miles of landfill site.

LITERATURE REVIEW

In 1977 Wong studied various mixtures of methane and carbon dioxide as fuels in an internal combustion (IC) single cylinder, four-stroke gasoline engine [15]. The engine was modified for fueling gaseous fuel. Brake horsepower, brake specific fuel consumption, concentrations of unburned hydrocarbon, nitric oxide and carbon monoxide were measured based on fuel quality. At the same engine speed (RPM), as the fuel quality lowered (the fraction of carbon dioxide increased), brake horsepower decreased while brake specific fuel consumption increased. When the fuel quality was lowered, unburned hydrocarbon and carbon monoxide emissions were increased. However, lowering the fuel quality tended to reduce nitric oxide emission.

In 1987 Caterpillar, Inc tested landfill gas operation in its 3516 spark-ignited, turbocharged, separate circuit, aftercooled, 16 cylinder engine 4211 in.3 displacement volume at Waste Management's CID landfill in Calumet City, IL [16]. In the study, the engine was modified for optimizing engine performance to meet the EPA standards for stationary gas engines. Some engine modifications were undertaken including enlarging and increasing the flow capacity, increasing flow pressure regulation and enlarging the fuel piping between the pressure regulator and the carburetor, and the addition of metering valves sized to operate on low-Btu fuel. This engine was not de-rated in spite of the low heating value of the landfill gas. The durability of the engine was demonstrated through 90 days of continuous operation.

In 1995 another engine made by Caterpillar, Inc was developed for landfill gas application [17]. The Caterpillar G3600 spark-ignition engine was developed to demonstrate engine performance and identify any issues caused by the application. Engine performance, exhaust emissions, and fueling system were estimated by simulated landfill gas\ in the lab and tested through field experiments.

The engine durability test was conducted for 12,000 hours.

Karim and Wierzba examined the mixtures of methane and carbon dioxides as a fuel in 1992 [18]. A single cylinder CFR engine was used for this study. The mean values of the brake power, the concentration of carbon dioxide and unburned methane in the exhaust, and the exhaust gas temperature were measured according to the variation of equivalence ratio. The brake power increased with the increase in equivalence ratio and decreased with carbon dioxide fraction in a fuel. The concentration of carbon dioxide in the exhaust increased with equivalence ratio and the amount of carbon dioxide in a fuel. Unburned methane increased near lean conditions, but sharply decreased at rich conditions. Higher carbon dioxide fraction in a fuel leaded higher concentration of unburned methane. The average exhaust gas temperature had the maximum value at the stoichio metric region, and decreased with the volumetric percentage of carbon dioxide. The evaluation of simulated biogas as a fuel for the spark ignition engine was studied by Huang and Crookes in 1997 [19]. A single-cylinder spark-ignition engine was operated on a simulated mixture fuel consisting of different fractions of natural gas and carbon dioxide with a variable compression ratio. The study covered a wide range of relative air-fuel ratios from lean to rich. The main effect of higher fractions of carbon dioxide was to lower nitrogen oxides while carbon monoxide and total hydrocarbon emissions were increased. At constant speed of 2000rpm and relative air-fuel ratio of 0.98 (fuel rich condition) with changes of CO2 fraction in the fuel mixture from 23.1% to 41.2%, CO emissions increased from 1.5% to 2.5% and THC emissions also increased from 500ppm to 680ppm, whereas NOX emissions decreased from 1200ppm to 1000ppm. Brake power also decreased with the presence of carbon dioxide in the fuel mixture from 6.95kW to 6.75kW. The study conducted by Shrestha and Narayanan in 2007 discussed effective ways for a spark ignition engine to produce power using landfill gas [20]. The engine performance and combustion characteristics of landfill gas fueled engines were studied by changing spark timing, compression ratio and composition of the landfill gas at different equivalence ratios from lean to rich conditions in comparison to methane operation. Engine performance deteriorated with increasing compression ratio and spark timing. The effects of landfill gas composition were more pronounced at lean and rich mixtures than at stoichiometric mixtures. In addition, the authors also tested the effects of hydrogen addition (up to 30%) to landfill gas. The appropriate amount of added hydrogen improved combustion characteristics and reduced cyclic variations of landfill gas operations at the lean and rich mixtures. For example, 5% added H2 increased the power of engine from 1.50kW to 1.75kW under 0.6 of equivalence ratio and 600rpm; also, it increased the thermal efficiency from 0.32 to 0.39 at the same condition.

CONCLUSIONS

The presence of CO2 in fuel mixtures deteriorated the engine performance and produced more pollutants in emissions than pure CH4. Engine efficiency was decreased by mixing with CO2 at same load conditions. As CO2 fraction in a fuel increased, the equivalence ration increased, which means more fuel was needed to generate same power output. NOX slightly decreased whereas CO and THC increased with CO2 fraction. Also, according to the increase in electrical engine load, engine efficiency and CO and THC emissions were lowered, which means higher engine load leads better combustion. The mixture of simulated landfill gas consisting of 50% CH4 and 50% CO2 and H2, CO and simulated synthesis gas consisting of H2 and CO (H2/CO = 2) were also tested for the IC engine. These three gases (H2, CO, and syngas) were added up to 15% to the fuel mixtures. These three gases not only lowered all emissions (CO, THC, and NOX) but also improved engine efficiency. However, when the fractions of H2, CO, and syngas in landfill gas fuel mixtures exceeded appropriate points, engine efficiency decreased and pollutant emissions increased; 10% was the most suitable fraction. Of these three gases: H2, CO, and syngas, syngas most effectively improved engine efficiency, and reduced pollutant emissions: CO, THC, and NOX. As a future work, it can be done to measure the portion of CH4 in THC emissions by using more sensitive analyzer such as micro GC. This work will allow finding a conversion of fuel mixture leading to more detailed analysis for the production of emissions

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