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COMBUSTION OF SIMULATED BIOGAS IN A DUAL-FUEL DIESEL ENGINE

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Abstract—Technology related to biogas has been steadily developed over the last 50 years from small individually designed units to larger production plants. The development, however, has largely taken place on the side of biogas production and anaerobic waste treatment. Utilization of the gas produced by these methods has only recently been the subject of more scientific evaluation. The transformation of energy through biogas into the thermodynamically higher valued mechanical energy successfully and economically is now the most important research area in this field.

Of the engine work already published, most concerns spark-ignited engines. The authors' research work concerns the use of biogas in dual-fuel diesel engines. It examines engine performance using simulated biogas of varying quality representing the range of methane:carbon dioxide composition which may be encountered in gas from different sources. The total programme includes the effects of biogas quality and of the proportion of energy from pilot fuel injection over a range of speeds and loads, investigations into the performance parameters over a range of compositions of gaseous mixture. A two-cylinder, indirect-injection diesel engine of stationary type is being used as the first experimental test bed in this work and the variation of quality is provided by mixing natural gas and carbon dioxide. A data acquisition system for in-cylinder pressure and crank angle is being used successfully and some emissions measurements are also available, particularly for CO and O_2.

One of the authors is from India where there is thought to be considerable potential for exploiting the gaseous products from resources such as biogas, landfill and sewage gas through small stationary dual-fuel engines for irrigation and CHP applications. The nature of combustion process in the dual-fuel engine is examined by the authors through pressure-crank angle data and studies of characteristics affecting engine efficiency. © 1998 Elsevier Science Ltd. All rights reserved

Biogas Dual-fuel engine Alternative fuels

INTRODUCTION

The gaseous fuels are getting more positive response from researchers and end-users compared with the past because of current unfolding developments. The first development of importance is certainly the issue of the 1990 s—the environment. Gas is clearly the fossil fuel of least environmental impact. When burnt, it produces virtually no SO_x and relatively little NO_x, the main constituents of acid rain, and substantially less CO_2, a key culprit in the greenhouse debate, than most oil products and coal. The second unfolding development is driven by technology. There has been a steady increase in the use of alternative transportation fuels. Our main emphasis is on the gaseous fuels. Use of natural gas for power generation in combined cycle plant has led thermal efficiency to 52% while it is only 40% from state-of-the-art coal or oil fired power plants which also require desulphurization. Other gases like biogas, landfill gas and sewage gas have also attracted the researchers worldwide to realise and tap their energy potential to the optimum use.

The analysis of the various gaseous fuels from the various sources like natural gas, biogas, landfill and sewage gas reveals that the main constituent contributing to the heating value of the fuel is methane. Thus methane number can be used to classify the various gaseous fuels in similar ways to octane number and cetane number being used for petrol and diesel respectively.

The focus of the present research is not only the use of biogas in internal combustion engines already explored very well by so many researchers [3, 4, 6–10] but to explore the effects of varying the quality of gaseous fuel in terms of the methane number of the fuel by mixing natural gas and carbon dioxide in different proportions while using gasoil as pilot fuel. It will be very

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significant to obtain the relationship of methane number versus efficiency of dual fuel engine and to compare the same with the diesel engine efficiency.

MODIFICATION IN INTERNAL COMBUSTION ENGINES WORKING ON GASEOUS FUELS

The modification of a spark ignition engine is comparatively easy as the engine is designed to operate on air/fuel mixture with spark ignition. The basic modification is the provision of a gas–air mixer instead of the carburettor. The engine control is performed by the variation of mixture supply, i.e. throttle valve position as has been the case with petrol fuel. Spark ignition engines converted to natural gas show a power decrease of 15–20% attributed to a decrease in volumetric efficiency because of the gaseous fuel and the lower flame speed of air–gas mixture compared with air–gasoline mixtures. This power loss can be decreased to some extent by utilising the higher compression ratio possible with gas and advancement in spark timing. In stationary applications this loss of power is less important as they are mainly run at full load.

In dual-fuel diesel engines, the normal diesel fuel injection system still supplies a certain amount of diesel fuel. The engine however induces and compresses a mixture of air and gaseous fuel which has been prepared in the external mixing device. The mixture is then ignited by energy from the combustion of the diesel fuel sprayed in. The diesel fuel spray is termed as pilot fuel. The amount of diesel fuel needed for sufficient ignition is between 10–20% of the amount needed for operation on diesel alone at normal working loads. It differs with the point of operation and engine design parameters. Operation of the engine at partial load requires a reduction of the fuel gas supply by means of a gas control valve. A simultaneous reduction of the air supply would, however, decrease the quantity induced hence the compression pressure and the mean effective pressure. This would lead to a drop in power and efficiency. With drastic reduction the compression conditions might even become too weak to effect self-ignition. Dual fuel engines should, therefore, not be throttled/controlled on the air side.

Biogas as a fuel for vehicles has been an issue since the 1950 s. While in Europe the use in tractors seems to be the issue [1, 2] in Brazil the aim is to substitute petrol and diesel fuel in the automotive sector using purified and compressed biogas or natural gas [11]. Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic conditions and can also be produced by partial combustion of biomass in a gasifier. A typical dry-gas composition [6] may be 18–20% CO, 8–10% CO_2, 18–20% H_2, 2–3% CH_4 and a balance of N_2. The widely variable composition of the gas from the gasifier makes this fuel better suited to diesel engines operating in a dual fuel mode. Mukunda *et al.* [6] have discussed the complete gasifier/diesel engine system in some detail. Stone *et al.* [8] have analysed biogas combustion (typical composition is 35% CO_2 with 65% CH_4) in spark-ignition engines by means of experimental data and a computer simulation.

"Ideally, there is a need for optimum variation in the liquid fuel quantity used any time in relation to the gaseous fuel supply so as to provide for any specific engine the best performance over the whole load range desired" [3]. Usually, the main aim, for both emissions and economic reasons, is to minimize the use of the diesel fuel and maximize its replacement by the cheaper gaseous fuel throughout the whole load range. The dual-fuel engine can operate effectively on a wide range of different gaseous fuels while maintaining the capacity for operation as a conventional diesel engine. Normally, the change over from dual fuel to diesel operation and vice versa, can be made automatically even under load.

EXPERIMENTAL SET-UP

The test engine for the present research work is a two-cylinder, four-stroke, water-cooled, indirect injection Lister Petter LPWS2 diesel engine. The set-up for experimental work including gas supply line with pressure cut-off and safety devices and other instrumentation used is shown in Fig. 1.