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RME or DME: A preferred alternative fuel option for future diesel engine operation

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Abstract

The twin challenges of fossil fuel depletion and environmental degradation, present engine and vehicle manufacturers with problems focused on future provision of both automotive power plant and conventional hydrocarbon fuels. In the drive to meet more stringent emission controls, many options have been identified, in the investigation of viable alternative fuels, and in the means of meeting the standards. While the operation of spark-ignition engines with natural gas is proven, other fuels are currently being explored for compression-ignition engines. In this study, di-methyl ether and rape-seed methyl ester, together with diesel fuel, were used, both as neat fuels and for pilot injection, in a natural gas dual-fuelled compression-ignition engine, to examine the performance and the levels of exhaust emissions. The merits and shortcomings as alternative fuels for diesel engines are discussed. While the ester performs much like diesel fuel in both modes, the ether produced lower specific oxides of nitrogen in dual-fuel operation.
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1. Introduction

High among the major challenges facing the industrialised nations today are: the economical use of existing fossil fuels and the development of suitable alternative and renewable fuels or blends, while considering their environmental impact. Reduction of emissions, to any great extent, without sacrificing fuel economy will be an enormous challenge. This may well be met more readily by use of the diesel engine, though tighter legislation is progressively being introduced to control particulate emissions. Exploitation of well-known alternative fuels that will meet the required air quality standards in the short-term could emerge as one of the most viable options.

Continued research into the performance of rape-seed methyl ester (RME) and di-methyl ether (DME) as fuels for diesel engines and of natural gas in dual-fuelled diesel engines as well as in spark-ignition engines is important. The latter is encouraged by large deposits of natural gas that have been discovered but are yet to be fully developed in the Middle East and other parts of the globe [1]. Waste derived and landfill sources of bio-gas are also the subject of assessment in other areas [2].

Understanding the complex phenomena in dual-fuelling, in which gaseous fuels interact with liquid fuels, in both the ignition delay period and the subsequent burning phases, is necessary and such processes need to be studied in depth. These studies will need to give consideration to both the physical and chemical characteristics of the fuels [3]. Fuel type, quality and characteristics have a vital role to play in meeting the current and future established standards. Liu and Karim identified, for example, a possible chemical interaction between the pre-ignition reactions of the pilot fuel and the reactions of the fumigated gaseous fuel within its oxidising surroundings [4].

RME, rape-seed oil trans-esterified with methanol to attain a higher cetane number and reduced viscosity, is a promising fuel for compression-ignition engines. It is a

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biodegradable and renewable, bio-mass based fuel. Its use, in recent years, has increased exponentially, particularly in Germany and neighbouring countries [5]. However, this contribution still falls dramatically short of total oil consumption in the same region. DME is a new, ultra-clean alternative fuel, currently under extensive investigation. Some of its characteristics include rapid evaporation, smoke-free combustion, low noise level combustion, Virtual non-toxicity and being in general 'environmental friendly' [6–9]. The results of the *Bio-DME project* in Sweden [10] demonstrate the advantages of DME and incidentally also those of natural gas, in terms of lower specific emissions in heavy goods vehicles, compared with both diesel fuel and RME. The motivating factors in the use of engines fuelled with DME or natural gas when compared with diesel fuel or RME, are the clean and efficient combustion characteristics leading to lower particulate emission. As well as lower Bosch smoke numbers, consistently around 0.2, Sorenson and Mikkelsen reported lower specific emissions of carbon monoxide (CO) and oxides of nitrogen (NO_x) but similar values of unburnt hydrocarbons (uHC), compared with diesel fuel in single-cylinder engine tests [11].

This present study explores the merits and factors that govern the use of DME and RME as fuels for diesel engines in the short-term future. Experimental tests were designed to run with DME, RME and vegetable oil as neat fuels and as fuels for pilot injection for a dual-fuel diesel engine. The main energy source in the latter was natural gas, ingested with the combustion air through the inlet manifold. The results may be compared with those with diesel fuel both in normal operation and under the same modes of dual-fuel operation, at two engine speeds. One of the major problems in the operation of spark-ignition engines with natural gas is the high NO_x that results from the high thermal efficiency, particularly as higher compression ratios can be used [2]. The effects of the alternative diesel fuels and their combustion characteristics, when used for pilot injection, in reducing exhaust emissions while maintaining fuel economy, in a natural gas fuelled compression-ignition engine are investigated. In particular, this is explored as an effective means of reducing NO_x emission, without increasing particulates or sacrificing fuel economy, when using DME or other alternative fuels, for pilot injection. The potential for reduction of NO_x to the specific limits of normal diesel operation, without the use of costly catalytic converters and with low particulate emissions, is a target that merits research.

2. Experimental equipment and test procedures

A Gardner 1L2, single-cylinder (bore: 108.0 mm; stroke: 152.4 mm) four-stroke, naturally-aspirated compression-ignition engine, with associated performance and emission instrumentation was used, having the principal components shown in Fig. 1. The emission test equipment was as used by Crookes and described in [2]. The cylinder pressure, temperatures and all emissions readings were sampled at high frequency using a data-logger and fed to a computer. For the single fuel only tests, a range of load setting to the maximum power output (14.5 kW) was used, at constant speeds of 1000 r/min and 1500 r/min, with fixed static injection timing of 24.5° before top dead centre (btdc) and constant compression ratio of 14:1. For the second-stage tests, natural gas from the domestic gas supply was fed to the engine, at a flow rate, from 10 l/min to 30 l/min, the experimentally determined, knock-limited range (at 1000 r/min and 1500 r/min). All tests were carried out at steady-state condition. Diesel fuel was used for pilot injection without changing the injection timing or the fuel setting for baseline load.

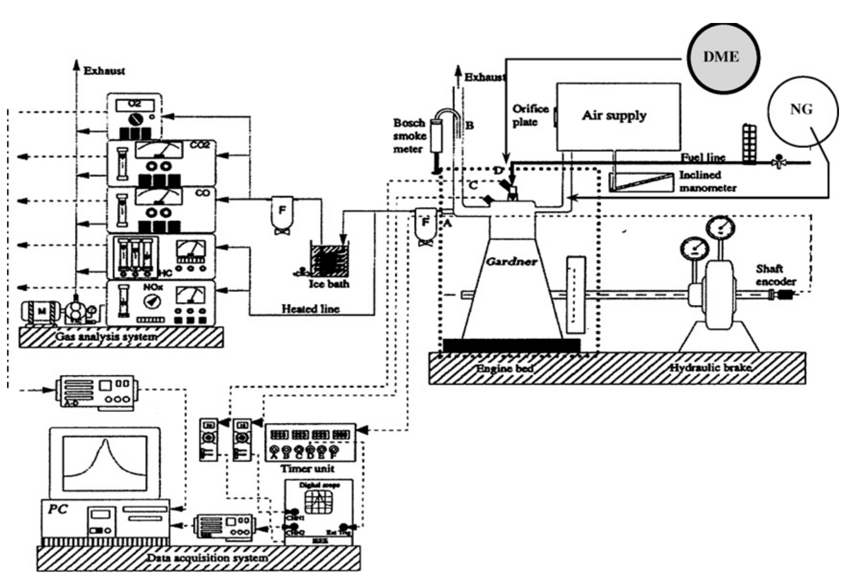

Fig. 1. Schematic lay-out of instrumented single-cylinder diesel engine in duel-fuel mode.

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