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The Effect of High Carbon Dioxide Content on the Performance and Emission Characteristics of a Direct Injection (DI) Compressed Natural Gas Engine

Wasiu B. Ayandotun[a], A. Rashid A. Aziz[b] and Morgan R. Heikal[c]

Mechanical Engineering Department, Universiti Teknologi PETRONAS, Malaysia

[a]wasiuayan@gmail.com, [b]rashid@petronas.com.my, [c]morgan.heikal@petronas.com.my

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Abstract. This paper investigates the potential of utilizing the undeveloped natural gas fields in Malaysia with high carbon dioxide (CO_2) content ranging from 28 to 87%. For this experiment, various CO_2 proportions by volume were added to pure natural gas as a way of simulating raw natural gas compositions in these fields. The experimental tests were carried out using a 4-stroke single cylinder spark ignition (SI) direct injection (DI) compressed natural gas (CNG) engine. The tests were carried out at 180ºCA BTDC injection timing and 3000 rpm, to establish the effects on the engine performance. The findings revealed that the brake torque decreased by 9% with 20% CO_2 proportion in the mixture due to the decrease in the heating value of the mixture. At the same proportion of CO_2, the brake specific fuel consumption decreased by about 8.5% and the brake thermal efficiency increased by 9.2%. There was a reduction in the unburnt hydrocarbons (THC) and carbon monoxide (CO) emissions by 15% and 89% respectively, but the NOx emissions increased by 78%. The utilization of natural gas with 20% CO_2 content as fuel in DI-CNG engine was found to be viable with insignificant drop in engine performance and with reductions in exhaust emissions.

Introduction

The search for alternative fuels for internal combustion engines with a view to improving the engine fuel economy and reducing harmful exhaust emissions becomes necessary [1] as the energy needs in the transportation sector is growing drastically due to the increase in the number of vehicles. However, fossil fuels, specifically crude oil, being the major sources of energy and fuel for transportation, power generation and other applications are depleting at alarming rates, leading to increases in their prices. Also the increasing consumption of these fuels is causing environmental pollution thereby causing global warming and health related problems. Therefore, dependency on fossil fuels (gasoline and diesel) calls for alternative energy sources for future energy needs. Moreover, with the increasing stringent emission standards continually legislated, alternative fuels are currently being used [2,3] to tackle the negative resultant effects of environmental pollution such as unburned hydrocarbon (uHC), carbon monoxide (CO) and nitrogen oxide (NOx) among others generated by all sectors.

In lieu of this, extensive research studies have been carried out to determine alternative fuels that are best suited for both spark ignition (SI) and compression ignition engines; and other applications. For spark ignition engines, biogas and syngas [4,5] have been studied and proved to enhance performance and reduce emissions under appropriate operating condition while for compression ignition engines, seed-oil bio fuels [5,6] have been examined and found to give similar performance and emissions when compared with conventional diesel fuels, particularly when blended with diesel fuel or emulsified with ethanol or water.

Natural gas is amongst the fast growing component of the world's primary energy consumption because of its availability, abundance and adaptability to the gasoline and diesel engines. Malaysia is endowed with abundant natural gas reserves of 2400 billion cubic metres (84.76 Trillion cubic feet) and thus ranked the 15th largest in the world [7]. However 37 Tcf of these natural gas reserves are non-developed due to the presence of large quantities of CO_2 (from 28% to 87%), thus

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