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Investigation on combustion characteristics and emissions of diesel/hydrogen mixtures by using energy-share method in a diesel engine

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ABSTRACT

Considering hydrogen as a clean alternative fuel for engines, this paper is to develop a procedure to add hydrogen in an intake manifold and to design an exhaust gas recirculation (*EGR*) system for a direct injection diesel engine. The cylinder gas pressure, air mass flow, fuel mass flow, and emissions (such as CO, CO_2, HC, NO_X, and smoke) were measured under various engine loads and 0%–40% *EGR* ratios adjusting the hydrogen-energy-share ratio at 0%–20%, meaning that the energy of hydrogen replaced 0%–20% that of diesel fuel. The combustion characteristics such as cyclic variations, heat release rate, brake thermal efficiency, and specific fuel consumption (*SFC*) were determined. The results show that the variation coefficient values of indicated mean effective pressure (*IMEP*) are from 0.9% to 2.8%. The rate of decrease in the smoke emission is 37.6%, and that in the NO_X emission is 59.5% for a 60% load, 40% *EGR* ratio, and 20% added hydrogen.

1. Introduction

During the past several decades, a diesel engine has proven to be one of the most effective energy conversion systems. It is widely applied to a power source for land vehicles, commercial marine vessels, and stationary power plants [1]. However, the crises of energy and environment are caused by consuming fossil fuels long and using the engines widely. Therefore, researchers around the world have been studying on technology for decreasing exhaust emissions from engines and on alternative fuels for solving these crises.

Hydrogen is considered to meet energy, environment and sustainable development needs [2]. It is also expected to be an ideal alternative for fossil fuel systems [3] such as *IC* (Internal combustion) engines. Compared with conventional fuels, hydrogen has the following characteristics [4–6], such as a long term renewable, recyclable and non-polluting fuel because it is without carbon. And hydrogen gains much higher flame speed and larger diffusion speed so it can benefit the energy efficiency and emissions. The limits of flammability of hydrogen vary from an equivalence ratio of 0.1 to 7.1, and the engine is hence operated with a wide range of air/fuel ratio. The lower heating value of hydrogen is much higher (120 MJ/kg) than that of diesel fuel (42 MJ/kg).

In the recent years, because of good combustion characteristics of hydrogen, scholars take seriously on the correlation of its characteristics, use, and storage. Using hydrogen to upgrade the engine performance has been tested on various engines [7–9]. Mohammadi et al. [10] tried to make hydrogen directly inject into cylinder of a single-cylinder test engine using a high-pressure gas injector. Their results indicated that direct injection of hydrogen prevented backfire, increased thermal efficiency and output power, and reduced NO_X emission under the high engine output conditions. Saravanan et al. [11,12] have done a series of studies on conducting hydrogen into a single-cylinder direct injection diesel engine at the intake port. The test results demonstrated that the brake thermal efficiency increased from 22.78% to 27.9% with 30% hydrogen enrichment, meanwhile smoke and NO_X (only under lean burn condition) emissions decreased. With 3.3×10^{-4} m^3/s hydrogen volume flow rate, using the *EGR* system increased the brake thermal efficiency, and the trends of NO_X, CO, CO_2 and smoke reduced significantly [11]. In addition, Saravanan et al. [12] varied the parameters such as injection timing and injection duration of hydrogen and kept the hydrogen volume flow rate at 1.67×10^{-4} m^3/s for various loads. They found that using port-injected hydrogen increased engine efficiency with a greater reduction in emissions. From the above papers cited, the use of hydrogen as a fuel in a diesel engine has been studied; however, the authors found that most of the experiments with adding hydrogen into the engine discussed how the volume flow rate of hydrogen affected the engine performance and emissions at a fixed *EGR* volume flow rate.

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