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Short Communication

Effect of hydrogen nanobubble addition on combustion characteristics of gasoline engine

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ABSTRACT

Hydrogen is an attractive energy source for improving gasoline engine performance. In this paper, a new hydrogen nanobubble gasoline blend is introduced, and the influence of hydrogen nanobubble on the combustion characteristics of a gasoline engine is experimentally investigated. The test was performed at a constant engine speed of 2000 rpm, and engine load of 40, 60, and 80%. The air-to-fuel equivalence ratio (λ) was adjusted to the stoichiometric ($\lambda = 1$), for both gasoline, and the hydrogen nanobubble gasoline blend. The results show that the mean diameter and concentration of hydrogen nanobubble in the gasoline blend are 149 nm and about 11.35×10^8 particles/ml, respectively. The engine test results show that the power of a gasoline engine with hydrogen nanobubble gasoline blend was improved to 4.0% (27.00 kW), in comparison with conventional gasoline (25.96 kW), at the engine load of 40%. Also, the brake specific fuel consumption (BSFC) was improved, from 291.10 g/kWh for the conventional gasoline, to 269.48 g/kWh for the hydrogen nanobubble gasoline blend, at the engine load of 40%.

1. Introduction

Due to limited fossil fuel resources, and further significant environmental problems, improving the combustion and emission performance of internal combustion engines (ICEs) has become an important issue. In recent years, many researchers have focused on the study of a clean alternative to conventional hydrocarbon fuels [1,2], and improvement of the ICE performance [3,4]. Hydrogen has become a clean substitute for hydrocarbon fuels in ICEs, because hydrogen is a potential energy that offers zero emissions of CO_2, CO, and HC [5].

Although hydrogen energy is considered as an ideal alternative for ICEs, there are some problems, such as low energy density, and insufficient infrastructure, and high cost as a primary fuel for ICEs. Ganesh et al. [6] experimentally investigated the performance of a hydrogen fueled spark ignition engine. The test results showed that the peak power output of

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the hydrogen engine was 20% lower than that of the gasoline engine. Also, the specific fuel consumption (SFC) and the total fuel consumption (TFC) with hydrogen are much lower, than those with gasoline. This is mainly attributed to the increased thermal efficiency and higher calorific value of hydrogen. Alternatively, the use of hydrogen blended with diesel and biodiesel, as well as gasoline and alcohol fuels, has been considered as a more practical way to improve combustion properties, and hence reduce emissions, and increase fuel conversion efficiencies [7–10]. Ji et al. [11] reported that the brake thermal efficiency was improved, and kept roughly constant in a wide range of excess air ratio, after hydrogen addition, for gasoline-fueled spark ignition (SI) engines. The maximum brake thermal efficiency was increased from 26.37% of the original engine, to 31.56% of the engine with a 6% hydrogen blending level.

In recent years, micro- and nano-bubble (MNB) technologies have drawn great attention, due to their wide applications in a wide variety of fields, such as water treatment [12], biomedical engineering [13], and nanomaterials. Although there still remains many questions concerning the nanobubble that are not clear, it has been revealed that the nanobubble maintains an adequate kinetic balance against high internal pressure, and is stabilized, because the surfaces of the nanobubble contain hard hydrogen bonds that may reduce the diffusivity of gases through the interface film [14]. However, there are very few studies concerning hydrogen nanobubble gasoline fuel, and its combustion performance for the ICE.

In this study, an attempt has been made to develop a new hydrogen nanobubble incorporated gasoline blend. The characteristic of the hydrogen nanobubble in the gasoline blend, and the effect of the hydrogen nanobubble on the combustion characteristics of a gasoline engine, were experimentally investigated.

2. Experimental setup

To generate the hydrogen nanobubble (HNB) gasoline blend, hydrogen gas (H_2, purity: 99.995%, Shinyoung Gas Co., Korea) and gasoline (Octane Number: 91–94, Hyundai Oilbank Co. LTD., Korea) were used. 15 L of gasoline was prepared for the characterization of hydrogen nanobubble into HNB gasoline blend, and combustion test. An additional purification of the gasoline was not performed.

In this study, a nanobubble generator with membrane module was used to produce the hydrogen nanobubble in gasoline. The nanobubble generator consists of a gas tank, gasoline tank and gas–liquid dispersion system, as shown in Fig. 1. The gas–liquid dispersion system has a membrane module, which is 75 mm long, and 20 mm in diameter, with a tubular membrane. The hydrogen gas is fed into the membrane module from a gas tank, using a gas regulator. The gas pressure is 0.5 MPa.

The dynamic viscosities of pure gasoline and HNB gasoline were measured, using a viscometer (LVT, Brookfield Engineering Laboratories, USA). Also, the surface tensions of pure gasoline and HNB gasoline was measured, using a Du Nouy tensiometer (No.3179, Itoh Seisakusho Co. LTD., Japan), which uses the Du Nouy ring method.

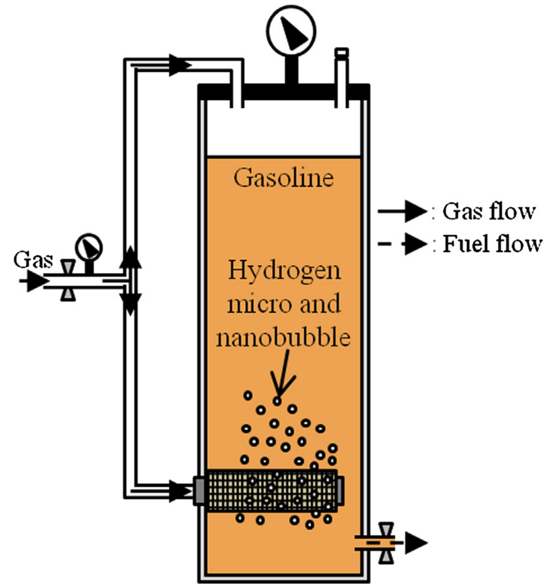

Fig. 1 – Schematic view of the nanobubble generator.

The bubble size distribution in nano-scale was measured, using the nanoparticle tracking analysis (NTA) method (NanoSight LM10-HSBFT14 with 405 nm blue laser, Quantum Design Korea, Korea). Based on a laser-illuminated microscopical technique, brownian motion of the nanoparticles was analyzed in real-time, by a high sensitivity electron multiplied CCD (EMCCD) camera. Bubble size distribution was subsequently measured by using each particle, which is simultaneously but separately visualized and tracked, by a dedicated particle tracking image analysis program.

The engine used in this study is a port fuel injection (PFI) and four-cylinder gasoline-fueled spark ignition (SI) engine (Sirius G4CP, Hyundai Motors), with 1997 cm^3 of displacement volume, and of natural aspirate (NA) type. It has a bore of 85.0 mm, stroke of 88.0 mm, and a compression ratio of 10. The rated maximum power and maximum torque are 98.57 kW at 6000 rpm and 180.44 N·m at 4500 rpm, respectively. The detailed specifications of the test engine are listed in Table 1.

Table 1 – Specifications of the test engine.

Engine type		Four cylinder SI engine
Bore		85.0 mm
Stroke		88.0 mm
Displacement volume		1997.0 cm^3
Compression ratio		10.0
Ignition system		DLI (Distributor Less Ignition)
Maximum power		98.57 kW @ 6000 rpm
Maximum torque		180.44 N·m @ 4500 rpm
Valve timing	IVO	15° BTDC
	IVC	53° ABDC
	EVO	51° BBDC
	EVC	17° ATDC