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The effects of hydrous ethanol gasoline on combustion and emission characteristics of a port injection gasoline engine

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ABSTRACT

Comparative experiments were conducted on a port injection gasoline engine fueled with hydrous ethanol gasoline (E10W), ethanol gasoline (E10) and pure gasoline (E0). The effects of the engine loads and the additions of ethanol and water on combustion and emission characteristics were analyzed deeply. According to the experimental results, compared with E0, E10W showed higher peak in-cylinder pressure at high load. Increases in peak heat release rates were observed for E10W fuel at all the operating conditions. The usage of E10W increased NO_X emissions at a wide load range. However, at low load conditions, E10W reduced HC, CO and CO_2 emissions significantly. E10W also produced slightly less HC and CO emissions, while CO_2 emissions were not significantly affected at higher operating points. Compared with E10, E10W showed higher peak in-cylinder pressures and peak heat release rates at the tested operating conditions. In addition, decreases in NO_X emissions were observed for E10W from 5 Nm to 100 Nm, while HC, CO and CO_2 emissions were slightly higher at low and medium load conditions. From the results, it can be concluded that E10W fuel can be regarded as a potential alternative fuel for gasoline engine applications.

1. Introduction

The shortage of petroleum and the stringent of emission have boosted the advancement of alternative fuels for internal combustion engines applications. In the last decades, ethanol gasoline blends have been investigated extensively and regarded as a potential alternative fuel for gasoline engine [1–3]. Researchers have investigated on performance and emissions of gasoline engines fueled with various ratios of ethanol gasoline blends and their application in ethanol flex-fuel vehicles [1–3]. According to their researches, ethanol additives bring oxygen into blends, increasing combustion efficiency and reducing hydrocarbon (HC) and carbon monoxide (CO) emissions. Besides, higher talent heat of ethanol gasoline blends makes mixture better, leading to a more complete combustion. However, due to the stronger hydrophilicity of ethanol, blended fuels mix easily with water in the air, which results in a lower stability of the blended fuels and a higher cost in storage and transportation. In addition, anhydrous ethanol production has high energy consumption, especially in the dehydration process. Hydrous ethanol, a promising additive for gasoline, can save a large consumption of energy and equipment without the further dehydration step [4–5]. Mixing with hydrous ethanol is becoming more popular due to both the conservation of energy and reduction of harmful emissions.

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Liu et al. [6] investigated the stability of E10 hydrous ethanol gasoline blend, using self-developed compound emulsifier. According to their experimental results, the stability of hydrous ethanol gasoline blend can be improved effectively with the method of emulsification, the addition of intensifier and antifreeze, and the increase of ethanol concentration can improve its low temperature stability. Kyriakides et al. used methyl tert-butyl ether (MTBE), tert-Amyl methyl ether (TAME) and palmitic acid as additives to prepare gasoline–ethanol–water ternary mixtures, which was proved that the additives promote water tolerance in gasoline–ethanol blends [7].

Munsin et al. [8] studied the effects of the use of hydrous ethanol with high water contents up to 40% on the performance and emissions of a small spark ignition engine. The effects of water contents in hydrous ethanol on engine performance and emissions were investigated. Schifter et al. [9] tested a single cylinder engine fueled by mid-levels (0–40% volume) hydrous ethanol and ethanol–gasoline engine with air/fuel mixture equivalence ratio varying from 0.9 to 1.1. According to Clemente et al. [10], with respect to ethanol-gasoline blend (22% ethanol and 78% gasoline), the use of hydrous ethanol (water concentration 7%) improved peak torque, peak power and SFC by 9%, 14% and 35%, respectively.

Costa et al. [11] evaluated a production 1.0–1 flex-fuel engine's performances when fueled with hydrous ethanol (ethanol with 6.8% water mass content) and regular gasoline (with 22% v/v anhydrous ethanol). Cordeiro de Melo et al. [12] performed an experimental investigation on the combustion and emission performance of a flex-fuel engine working with different hydrous ethanol blends. According to their research, NO_X results presented complex trends with ethanol addition, depending on the operating condition, spark advance timing and other parameters.

According to the previous literatures above, it can be found that researchers focused on the stability of hydrous ethanol gasoline blend and its influences on performance and emissions of engines or flex-fuel vehicles. There is still the need of additional research to better understand the effects of the blends and the engine loads on a port injection gasoline engine's combustion and emission characteristics.

To evaluate the effect of the addition of ethanol and water on combustion characteristics deeply, this study compares the combustion characteristics of hydrous ethanol gasoline (E10W), anhydrous ethanol gasoline (E10) and pure gasoline (E0) in a port-injected gasoline engine at various load conditions. Furthermore, to enrich the emission characteristics, nitrogen oxides (NO_x), CO, HC, and carbon dioxide (CO_2) emissions will be studied in detail over a wide range of engine load, from 5 Nm to 100 Nm. This case study is the comparative and further investigation on combustion characteristics of three fuels and it also enriches the investigations of emission characteristics of hydrous ethanol gasoline. Thus, this study is helpful for the evaluation of hydrous ethanol gasoline (E10W) as an alternative fuel for gasoline engine applications.

2. Engine test

2.1. Experiment setup

The experiment was conducted on a four-cylinder, port injection, and electronic controlled automotive engine. The detailed specifications of tested gasoline engine are listed in Table 1. The engine was loaded with a GW160 eddy current dynamometer. A pressure transducer, Model Kistler 6056A, was installed to monitor the in-cylinder pressure connected with a charge amplifier, Model Kistler 2613B. The cylinder pressure data was recorded in 0.5° CA increments. For each test point, 100 consecutive cycles were recorded and computed by combustion analyzer DEWE-5000. The exhaust gases including NO_X, CO, HC and CO_2 were measured with a gas analyzer, Model AVL Digas 4000. NO_X and HC emissions were measured using a chemiluminescent detector (CLD) and flame ionization detector (FID), respectively. CO and CO_2 were measured by the method of nondispersive infrared (NDIR). The accuracies of the measurements in this experiment are presented in Table 2. The uncertainty of this experiment was determined by parameters including engine speed, engine torque, crank angle, in-cylinder pressure, NO_X, CO, HC and CO_2. The total uncertainty of this experiment was computed to be 1.16% with the method of root-sum-square (RSS) [13]. The experimental setup is shown in Fig. 1.

2.2. Test fuel and method

In this study, the engine was tested and fueled with commercially available pure gasoline which also was the base fuel, 10% anhydrous ethanol-90% gasoline and 10% hydrous ethanol (containing 5% water by volume)-90% gasoline. Physical and chemical properties of anhydrous ethanol, hydrous ethanol and gasoline are shown in Table 3. The engine was initially run

Table 1
Main specifications of the tested engine.

Type	Port injection, naturally inspired
Bore × stroke	75.0 mm × 84.4 mm
Compression rate	10.5:1
Rated power	80 kW@6000 r/min
Rated tongue	130 Nm@4500 r/min
Displacement	1.5 L