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Effect of hydrogen addition on performance of low heat value gas engine

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ABSTRACT

Experiment of low heat value gas blended with hydrogen in a modified single-cylinder CNG engine is studied. The components of low heat value gas contain natural gas and N_2, the natural gas contents from 60% to 80% by volume, N_2 content is from 20% to 40% by volume. The hydrogen blending ratio is from 10% to 30% by volume. Results show that with the increase of N_2 proportion, the engine power, CO and NO_x emissions are decreased, but HC emissions is increased. When hydrogen blending ratio is increased, CO emission is increased while HC emission is decreased. When properly increases hydrogen blending ratio, the maximum cylinder pressure and engine torque are increased. However, large hydrogen blending ratio will decrease engine power. NO_x emission is related to N_2 proportion of low heat value gas.

Introduction

With the development of automobile industry, petroleum fuel shortages and environmental deterioration have become major challenges for human society. To seek cleaner fuels and reduce harmful emissions has become the focus point in the field of internal combustion engines and automotive industry. Among lots of alternative fuels, the low heat value gaseous fuel has pay close attention to governments because it has wide range of resources, waste utilization, cheap, complete combustion and low emissions. To develop low heat value gaseous fuel engine has become an important strategy of green projects initiative.

Research on the low heat value gas engine focuses on biogas engine and coal bed methane engine. K. C. Midkiff [1] has studied engine emission characteristics fueled with 4 different ratio of low heat value gas and found that different ratio has remarkable influence on engine emissions. Saiful Bari [2] has studied CO_2 fraction impact on the low heat value gas engine performance, and found when CO_2 fraction reached 40%, the low heat value fuel gas engine performance was the same as CNG engine, and while CO_2 fraction reached 30% the part of low heat value fuel gas engine performance improved than CNG engine. Anne Roubaud [3] has used the pre-combustion chamber to realize the thin equivalence ratio to improve low heat value gas fuel engine combustion and emission characteristics significantly through the change of combustion chamber structure. David [4] has studied the coal bed fraction influence on engine emission characteristics with EGR. Huang [5] has researched the fraction of CO_2 and N_2 added to natural gas on the engine power, economy and emissions performance. This research indicated that HC emissions increased, CO_2 and NO_x emissions reduced compared with CNG engine. And many references [6,7]

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indicated that the low heat value gas has important properties compared with other popular gaseous fuels.

In this work, small amount of hydrogen was added to low heat value gas to improve its combustion characteristics. The blended fuel was then tested in a single cylinder CNG engine at different hydrogen levels. The components of blended fuels contain CNG and N_2, and the CNG content is from 60% to 80% by volume, N_2 content is from 20% to 40% by volume. Through experimental study on combustion and emission characteristics of different components of CNG and N_2 levels, the influence of fuel composition change on engine performance is analyzed, and the engine combustion and emission characteristics are experimental studied by using different percentages of hydrogen mixed with the blended fuels in internal combustion engines.

Experimental setup and experiments

The original engine was a single cylinder, four strokes, air cooled spark ignited ZS1100M CNG engine with a displacement volume of 0.9 L and an output of 10.3 kW at 2000 rpm and 53.5 Nm at 1400 rpm, and the bore × stroke is 100 × 115 mm, the chamber type is shallow basin shaped, the compression ratio was 10.2. The modified work is to install two gas fuel injection valves at the root of intake pipe, and the two valves are connected to different kinds of gas fuel supply systems. The integrated control of fuel injection timing, injection quantity and ignition timing is achieved through electronically controlled injection system and high-energy ignition system.

The blended low heat value gas is composed of different proportions of natural gas (CH_4 content was 96%, other gas components accounted for 4%) and N_2. After these two gaseous fuels pre-blended, through the decompression device into the injection valve installed at the root of the inlet, the ejected gas fuel is mixed with air and then into the engine to burn. When blended with hydrogen gas, the blended low heat value gas fuel form two kind of gas injection system and

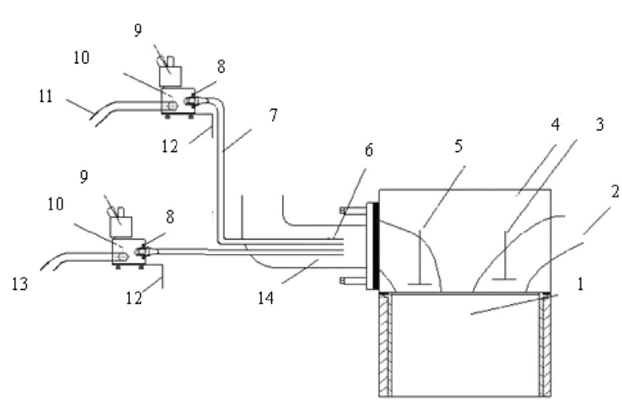

Fig. 1 – Experimental setup of the low heat value gas engine 1-cylinder, 2-exhaust pipe, 3-exhaust valve, 4-cylinder head, 5-intake valve, 6-nozzle, 7-pipeline, 8-seals, 9-ejector, 10-common rail block, 11-fuel gas intake pipe, 12-common rail bracket, 13-blended gas inlet pipe, 14-intake manifold.

hydrogen fuel are injected into the inlet respectively, mixed with air and then into the cylinder. The scheme view of the fuel supply injection program is shown in Fig. 1.

During the experiment, four kinds of energy content of the mixtures mixed with CNG and N_2 are used, they are respective from 80% CNG to 20% N_2 by volume, from 70% CNG to 30% N_2 by volume, from 60% CNG to 40% N_2 by volume and from 50% CNG to 50% N_2 by volume, and then blended with different proportions of hydrogen respectively. At 1500 r/min load characteristic curves, the cylinder pressure values and harmful emissions have been obtained by measurements on engine fueled with different compositional of low heat value gas and hydrogen. Since the engine work load is lower when operating the blended fuel of the ratio from 60% CNG to 40% N_2, and the engine can not start when burning the blended fuel from 50% CNG to 50% N_2, so the characteristic curves of these two blended fuel without hydrogen addition did not appear.

Results and discussion

Emission characteristics of low heat value blended H_2

Fig. 2 (a) shows CO emission characteristics of the low heat value gaseous with the N_2 fraction of 20% mixed with different proportions of hydrogen. In the entire load range of the engine operation, CO emissions of the low heat value gas with the H_2 fraction of 10% are much lower than that with the H_2 fraction of 15%.Fig. 2 (b) shows CO emission characteristics of the low heat value gaseous fuel with the N_2 fraction of 30% mixed with different proportions of hydrogen. With the increase of hydrogen fraction, CO emissions increased in the entire load range. The reason is that the fuels blended with amount of hydrogen can attract more and more oxygen to involve in the reaction, lead to relative hypoxia for CNG combustion, and resulting in increased CO and HC emissions. Fig. 2 (c) shows CO emission characteristics of the low heat value gaseous fuel of 40% N_2 mixed with different proportions of hydrogen. CO emissions of the low heat value gas fueled with blending 15% H_2 is significantly higher than blending 10% H_2 at low load, but at high load CO emissions of both blending hydrogen fuels is close to zero. Because of relative rare natural gas in the fuel blended with 40% N_2, the engine is under lean combustion state and in the coupled with the in–cylinder combustion temperature increased due to hydrogen combustion, the result of natural gas causes complete combustion, and CO emissions have lower level.

HC emissions of low heat value gas with the fraction of 20% N_2 blended with different proportions of hydrogen is shown in Fig. 3 (a). It is clear that HC emissions of the low heat value gas with the H_2 fraction of 15% are much lower than that with the H_2 fraction of 10%. The reason is that compared with the low heat value gas with the H_2 fraction of 10%, the in–cylinder combustion temperature is higher for the low heat value gas with the H_2 fraction of 15%, and promoting the oxidation reaction of HC, and HC in the gap is increased the degree of oxidation, thereby HC emissions reduced. Fig. 3 (b) indicates HC emissions of low heat value gas with the N_2 fraction of 30% blended with different proportions of hydrogen. Over the