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Research Paper

Experimental investigation about effect of glow intensity on combustion characteristics for a micro IC engine with platinum wire glow-ignition

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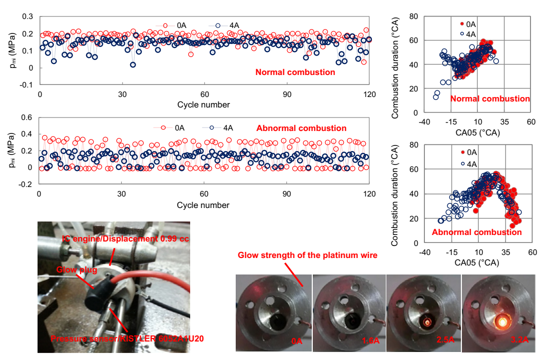
HIGHLIGHTS

- Enhancing glow intensity to get better in-cylinder micro combustion was proposed.
- A miniature IC engine of 0.99 cc displacement was modified, reassembled and tested.
- Increasing glow intensity has no remarkable improvement for normal combustion.
- Enhancing glow intensity contributes to abating misfiring for abnormal combustion.
- Electrical heating glow-ignition is an underlying way for meso-scale IC engines.

GRAPHICAL ABSTRACT



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ABSTRACT

Combustion efficiency and combustion stability in micro space are the key constraints to scale down the structure of the miniature internal combustion engines from small-scale to meso-scale. For the glow-ignition combustion mode of the miniature internal combustion engines, enhancing the glow intensity of platinum wire by additional electrical heating to get better combustion characteristics was proposed. An experimental platform for combustion test was set up, and glow-ignition combustion characteristics of a miniature internal combustion engine with displacement of 0.99 cc were diagnosed. It is indicated that improvement of in-cylinder combustion characteristics due to enhancing the glow intensity is not obvious under normal combustion condition; instead, with the increasing of the glow intensity, cyclic variations as well as misfiring phenomenon have a tendency of deterioration. However, under severe partial burning and misfiring conditions, enhancing the glow intensity can remarkably decrease the high rate of misfiring, get better combustion stability and broaden the limiting combustion regime, showing a real effect at least partly to advance the starting time of combustion and shorten the combustion duration. Electrical heating glow-ignition combustion can be considered as one of underlying approaches to extend the limit of combustion stability for prospective meso-scale internal combustion engines.

1. Introduction

Due to super energy density that micro heat engines using liquid hydrocarbon fuel can provide, the micro heat engines show the huge competitive advantage over the existing $LiSO_2$ battery system, and possess significant application prospect and research

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value [1–6]. Nowadays, a miniature internal combustion engine (referred to as miniature IC engine) using alcohol-based blend fuel has been successfully developed to 5 mm × 5 mm size (cylinder bore 5 mm and stroke 5 mm). However, micro space combustion efficiency and combustion stability are still the key constraints to scale down its structure further into meso-scale [7–12].

Constrained by the micro space structure, spark ignition cannot be applied to the miniature IC engines so that combustion mode of platinum wire glow-ignition has to be organized. However, the glow-ignition combustion tends to be high cyclic variation, slow heat-release rate, frequent partial burning and misfiring [13–15]. As the combustion space continues to be scaled down to the objective of 1 mm × 1 mm size (cylinder bore 1 mm and stroke 1 mm), phenomena of partial burning and misfiring should become more prominent. For further scaling down the structure of the miniature IC engine from small-scale to meso-scale, enhancing the glow intensity of platinum wire to get better in-cylinder combustion characteristics was put forward.

In order to understand the effect of enhancing the glow intensity on micro combustion characteristics, an experimental platform of combustion diagnosis was set up. As a tested prototype, a two stroke miniature IC engine with platinum wire glow-ignition was structurally modified and reassembled for installation of pressure sensor. Displacement of the miniature IC engine is 0.99 cc, which is the minimum displacement IC engine that has been used for in-cylinder micro combustion test so far [13–15]. During the test, the platinum wire was additionally electrically heated by switching on DC current with different intensity to realize the adjustment of the glow intensity. The in-cylinder combustion characteristics of the miniature IC engine under different glow intensity conditions were investigated, and the actual beneficial effects of the electrical heating for platinum wire on the micro combustion were evaluated and discussed.

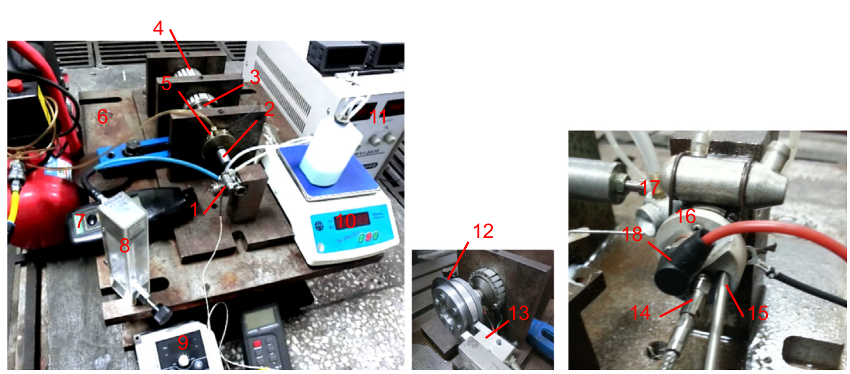
2. Test and evaluation of self-sustained glow-ignition combustion

2.1. Experiment set up

A miniature engine test bench is made up of driving system, load absorption system, data acquisition system. As shown in Fig. 1, a motor (4), a hysteresis brake (5) and a miniature IC engine (1) are installed in series on a base plate (6) by coupling (2) and coupling (3). The motor (4), as a driving unit, drives the rotary parts of the test bench to be rotated at a designated speed. The hysteresis brake (5), as a torque-balance device, balances the output torque of the miniature IC engine (1) and the driving torque of the motor (4). The brake power of the hysteresis brake (5) can be measured under the condition of assembling the fired miniature IC engine (1), and then compared with the brake power which be measured under the condition of disassembling the miniature IC engine (maintaining the motor in same operating state). Difference of the brake power between the two operating state conditions is equal to the output power of the miniature IC engine (1).

The miniature IC engine (1) is a two-stroke, single cylinder, crankcase-scavenging, air-cooled, reciprocating engine with the following dimensions: bore 11.25 mm, stroke 10 mm, and geometric compression ratio of 8, which is the minimum displacement IC engine that has been used in-cylinder combustion test among international literatures so far [13–15]. A special cylinder head (16) for the miniature IC engine (1) was redesigned, fabricated and reassembled for installation of pressure sensor. A carburetor (17) is used to control the fuel flow into the engine induction system and provide methanol-castor oil-nitromethane blend fuel (volume coefficient for each ingredient is 67%, 18% and 15% respectively). In the blend fuel, castor oil added into the mixture fuel is used to ensure the lubrication of the moving components. Moreover, a platinum wire glow plug (18) installed on the special cylinder head (16) is used to ignite the premixed fuel-air mixture. The platinum wire in the glow plug (18) has a diameter of 0.3 mm and an effective length of 3 mm. Under normal combustion condition, glow condition of the platinum wire is self-sustained by the released heat of in-cylinder combustion.

In the test bench, the motor (4) is a GRZ1500 type high-speed driving motor, matched with E300-2S0015 type frequency converter (9) whose output frequency can be adjusted from 0 Hz to 600 Hz. The AHB-202 type hysteresis brake (5) has a good linear relationship between its controlling current and output torque, its maximum continuous brake power under the forced cooling condition is about 200 W. WYJ-30-30 is an adjustable DC regulated power supply (11), which is used to control the input current of the hysteresis brake (5) to achieve the adjustment of brake torque. The test bench is also equipped with an optical speedometer (7), a K-type thermocouple (15) and a micro flow meter (8) to measure running parameters of the miniature IC engine (1) such as cylinder head temperature, engine speed and intake air mass flow. Weighing equipment (10) is also adopted to measure the fuel consumption of the miniature IC engine (1). Both the air mass flow



1—Miniature engine; 2/3—Coupling; 4—Motor; 5—Hysteresis brake; 6—Base plate; 7— Optical speedometer; 8—Micro flow meter; 9—Frequency converter; 10—Weighing equipment; 11—DC regulated power supply; 12—Marker disk 365X360; 13—Pulse-pick-up 365X01; 14—Pressure sensor; 15—K-type thermocouple; 16—Special cylinder head; 17—Carburetor; 18—Glow plug

Fig. 1. Schematic of the miniature engine test bench.