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Instability of flame in micro-combustor under different external thermal environment

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ABSTRACT

This experiment investigates the performance of a micro-combustor made of a quartz tube. Its surface heat loss is controlled by external wind, the wind temperature ranges from 277 to 1001 K. Compared with the cold wind at 277 K, warm wind at intermediate temperature of 380 K helps stabilize the flame. Because it decreases the surface heat loss, thus inhibits extinction. However, extremely hot wind of 1001 K makes blowout happen easily. The phenomenon is analyzed. The micro-flame retreats to the combustor inlet due to the enhanced heat recirculation at extremely hot wind, which induces insufficient preheating. Subsequently, blowout occurs.

1. Introduction

Micro-power generators supply electricity for portable electronic devices, such as laptops, cellular phones, which require high-density power source for long period of operation time [1]. The micro-power generators show better performance than conventional batteries if only the efficiency is higher than 1% [2].

Epstein of Massachusetts Institute of Technology suggests the first micro-gas turbine [3]. However, the problems of manufacture and assembly are difficult to solve in micro-scale. Then micro-power converter based on thermoelectric is developed, which transfers heat into electricity without mechanical device [4]. But the low temperature difference in micro-scale inhibits heat transfer, thermophotovoltaic material converting radiant energy is then proposed [5], whose convention efficiency is too low to satisfy practical requirement. Other kind of micro-power converter, such as piezoelectric type, is also a good choice [6], but it needs to cooperate with micro-prime motor.

However, the heart of micro-power generator, micro-combustor, has many problems different from the conventional one. In micro-scale, because the large surface area-to-volume ratio increases the surface heat loss, extinction occurs easily [7]. Another factor affecting the flame stability is the quenching distance, which has the scale of millimeter, and equals to the dimension of micro-combustor [8]. Moreover, because of the shortened heat diffusion characteristic time in micro-scale, the heat spread fast, thus induces uniformization of temperature difference. The small hydrodynamic diameter of micro-combustor induces flow laminarization, but the boundary layer is thick and affects the velocity distribution and flow resistance [9,10].

New types of micro-combustor are also proposed for improvement. For example: swiss-roll combustors stabilize flame through heat recirculation [11]. Inactive micro-combustor wall could eliminate radical quenching [12]. Thermally stabilized burners could utilize upstream heat conduction along the combustor wall [13]. Applying catalyst to micro-combustor would decrease the activation energy of micro-combustion [14].

Micro-combustors have extremely high surface heat loss [7], thus decreasing surface heat loss may improve its stability. However, according to numerical simulation [15], micro-flame extends in adiabatic combustor. Subsequently, under lower surface heat loss, the extension of micro-flame may be constrained by micro-combustor, and induce negative effects. Therefore, the effects of decreasing surface heat loss should be tested through experiment.

In this experiment, a micro-straight-tube combustor is tested, and its surface heat loss is controlled by external wind at different temperatures. The performance of the micro-combustor under different operational conditions is investigated to analyze the effects of surface heat loss on its stability.

2. Experimental apparatus

Fig. 1 gives the schematic diagram of the experimental apparatus. Fig. 2 gives the according picture. It consists of gas feed system,

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