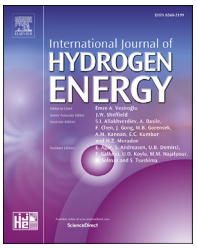
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–11

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he



Effect of micro-pin-fin arrays on the heat transfer and combustion characteristics in the micro-combustor

Jianfeng Pan[*], *Jian Zhu*, *Qisheng Liu*, *Yuejin Zhu*, *Aikun Tang*, *Qingbo Lu*

School of Energy and Power Engineering, Jiangsu University, Zhenjiang 212013, PR China

ARTICLE INFO

Article history:
Received 13 April 2017
Received in revised form
19 June 2017
Accepted 20 June 2017
Available online xxx

Keywords:
Micro-combustor
Hydrogen/air
Numerical simulation
Heat transfer enhancement

ABSTRACT

Micro-combustor is an important component elements of the micro-thermophotovoltaic (MTPV) conversion device. The combustion stability is critical to improve its thermal performance, and thus three kinds of combustors are compared by computational fluid dynamics (CFD), which includes single – channel combustor, alternate permutation combustor and in-line combustor. The influences of micro-pin-fin arrays on the performance of the micro-combustor are discussed. Results indicate that the maximum surface temperature of combustor with fins is about 100 K higher than that without fins and the mean temperature and heat flux of in-line combustor are always higher in magnitude than those of the alternate permutation combustor. Analysis in this paper reveals that comparing with single-channel combustor, the micro-combustor with fins greatly enhances the heat transfer process through the wall. There are low velocity zones in the tail of fins, which can gather the reactants and prolong the residence time which make the combustion more sufficient and improve the effect of stable combustion. Meanwhile, under calculated conditions, the influence of micro-pin-fin arrays on the combustion reaction is stronger as the flow rate increase. The fin array in micro-combustor does not only improve the wall temperature but also minimize the wall temperature difference along the axial direction. Moreover, when the inlet velocity is larger than 4 m/s, the hydrogen conversion ratios of micro-combustors with fins was not strengthened obviously with the further increase of inlet velocity.

Introduction

The micro power system based on hydrocarbon fuel has a broad potential application, since it has many distinct advantages in low cost, high energy density, compact and portable. As the core component of micro power system, micro combustor has a great influence on the performance of the whole system. With the decreasing of size of micro combustor, the ratio of surface-to-volume and the heat loss increase, which ultimately result in low combustion efficiency and instability of flame.

Many scholars have carried out lots of theoretical analysis, numerical calculations and experimental researches on micro-/meso-scale combustors to reduce heat loss and improve flame stabilization. Thermal managements, such as

* *Corresponding author*. School of Energy and Power Engineering, Jiangsu University, 301 Xuefu Road, Zhenjiang, 212013, PR China.
E-mail address: mike@ujs.edu.cn (J. Pan).

http://dx.doi.org/10.1016/j.ijhydene.2017.06.164
0360-3199/

heat recirculation and heat loss control, are effective ways to suppress the negative effect of heat losses and thus sustain a stable flame in small devices. Federici and Vlachos [1] investigated the stability of flame in a single-channel heat recirculation micro-combustor, and noted that the heat recirculation seriously affects blow-off limit due to preheating of the inlet flow, but has a minimal influence on extinction. E et al. [2] proposed a novel micro-combustor for non-premixed hydrogen-air combustion and studied the mixing performance of hydrogen/O_2 in it. It is shown that porous media combustion can increase flame stability and obtain higher fuel conversion rate compared with the free flame combustor [3–6]. Pan et al. [7] studied the effect of several major parameters on micro combustion in micro porous media combustor. The work showed that porous media material with low specific heat ratio and high thermal conductivity results in more uniform temperature distribution on the wall. Another way to extend the classical flammability limits and improve flame stability is adding catalyst. Pan et al. [8] also discussed the influences of the intermediate and final species from heterogeneous reactions in a catalytic combustor. The simulation consequences showed that the combustor performance can be commonly promoted in the hetero-/homogeneous combustion system due to the existence of catalysis.

Although different kinds of improve combustion methods have been reported in previous literature, simple yet effective methods are still desirable to widen the stable operating range of combustion-based micro-power generation systems. It is widely convinced that micro-combustor with a bluff body or a backward facing step chamber is extensively used for flame stability. Fan et al. [9–11] comprehensively investigated the influences of size and shape of the bluff body and the solid material on the blow-off limit of micro-combustor. Yang [12] and Pan [7] et al. researched on the property of combustion and micro cylindrical combustors with and without a backward facing step were compared. The result of which showed that the step was very helpful in controlling flame position and broadening the operational range of flow velocity. Mei et al. [13] designed a micro-reactor with micro-pin-fin arrays (MPFAR) for hydrogen production via methanol steam reforming, and found that the methanol conversion rate in the MPFAR is higher than that in a micro single-channel. Reyes et al. [14] studied the effect of tip clearance in micro channels on the performance of heat transfer and pressure drop, and optimized the tip clearance accounting for both thermal and pressure drop performance based on the experimental results. Tang et al. [15] researched a new type of micro planar combustor which has parallel separating plates in the combustion channel. The results showed that compared to single-channel combustor, the new combustor can achieve a higher mean temperature of the radiation wall due to the enhancement of heat transfer, and it becomes more obvious with the increase of plate number. Su et al. [16] also proposed a micro-combustor with multiple-channel which is of paramount importance for the micro-TPV system.

New types of micro planar combustor with different micro-pin-fin arrays are proposed to improve the combustion stability. Researchers have shown that micro-fin has an obvious influence on the heat transfer and combustion characteristics even though only few of the above-listed studies mentioned this aspect. In this article a new type of micro planar combustor with micro-pin-fin arrays was researched by simulation method. Combustors with and without micro-pin-fin arrays are compared and their effective effects are analyzed. The characteristics of heat transfer and combustion in the micro-combustor of premixed hydrogen/air are obtained by changing the arrangement of fins, so as to provide some valuable reference for further optimization.

In order to further study the influence of fins on the micro-combustion heat transfer and combustion characteristics, the

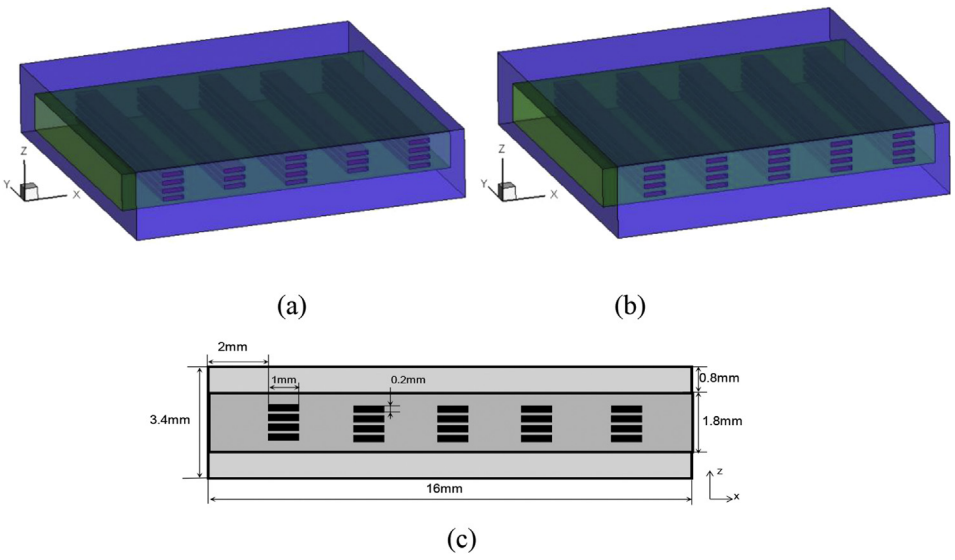


Fig. 1 – Schematic diagram of the micro-combustor with micro-pin-fin arrays. (a: alternate permutation combustor; b: in-line combustor; c: geometric dimension).

Please cite this article in press as: Pan J, et al., Effect of micro-pin-fin arrays on the heat transfer and combustion characteristics in the micro-combustor, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.06.164