Combustion characteristics of butane in a meso-scale burner with ordered porous media

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1. Introduction

Porous media combustion (PMC) has the characteristics of higher flame speeds, extended flammability limits, lower pollutants emissions, and enhanced heat transfer[1]. Foamed porous ceramics manufactured by traditional methods have nonuniform pore size and closed cells, which has an adverse effect on the combustion performance. Pore-scale simulation shows that the nonuniform size and distribution of pores causes the inhomogeneity of local reaction zone, flow field and temperature distributions[2]. Chen et. al[3] found that the inhomogeneous preheating temperature distribution would cause the inclination of flame front in packed bed. In recent years, the additive manufacturing technology of ceramic materials has developed rapidly, which has the potential to improve the uniformity of porous ceramics and realize the positive design of porous structures. To make the structure more similar to foamed porous media, the cell is a tetradecahedron in this study. The ordered porous media are produced by additive manufacturing, and the combustion characteristics of butane in the material are explored.

2. Experiment setup

The design process of additive manufacturing of porous media is shown in Fig. 1. The cell of porous media is a tetradecahedron, which is the Kelvin model. The porosity and pore diameter can be calculated according to the rod length and diameter, the formula is as follows:

$$\varphi = 1 - \frac{9.425}{8\sqrt{2}}\left(\frac{D_s}{l}\right)^2 + \frac{3.33}{8\sqrt{2}}\left(\frac{D_s}{l}\right)^3$$

$$D_p = \sqrt{3}l - D_s$$

The rod length (l) is 2.0 mm and the diameter of the rod (D_s) is 1.2 mm. The porosity of the porous media is 0.764, which becomes 0.758 after structural smoothing. The material is alumina, and the overall size is 18*18*52mm.

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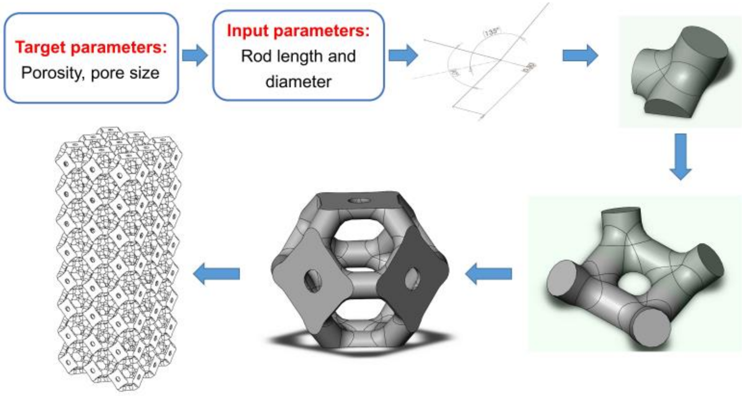

Fig. 1 Design process of porous structure

The experimental system is shown in Fig. 2. The burner is a two-stage burner, the upstream porous medium (PM1) is a zirconia ceramic ball with a diameter of 2 mm, and the downstream is additively manufactured porous alumina (PM2). In order to facilitate the observation of the flame, the burner uses a square-section quartz tube, as shown in Fig. 2(b). The flow of compressed air and butane (95% purity) is adjusted by mass flow controllers. Seven thermocouples are used to measure temperature of the wall, the upstream packed bed and the outlet. A infrared thermal imager was used to measure the wall temperature. In addition, a flue gas analyzer is used to measure the exhaust gas composition.

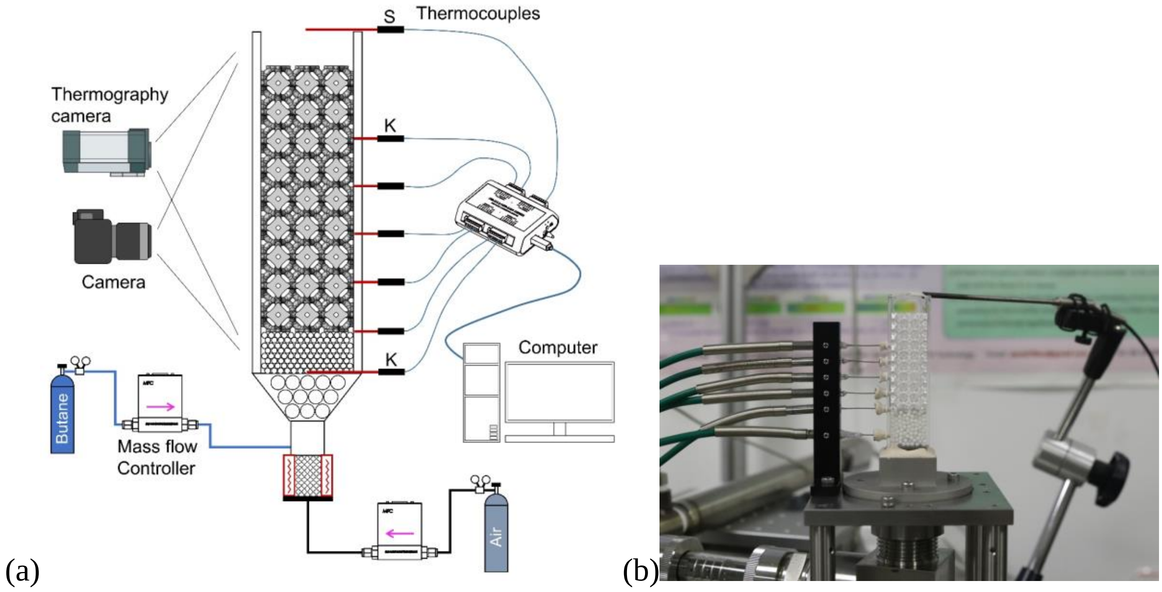

Fig. 2 (a) Schematic of the experimental system, (b) photograph of the burner.

3. Results and discussion

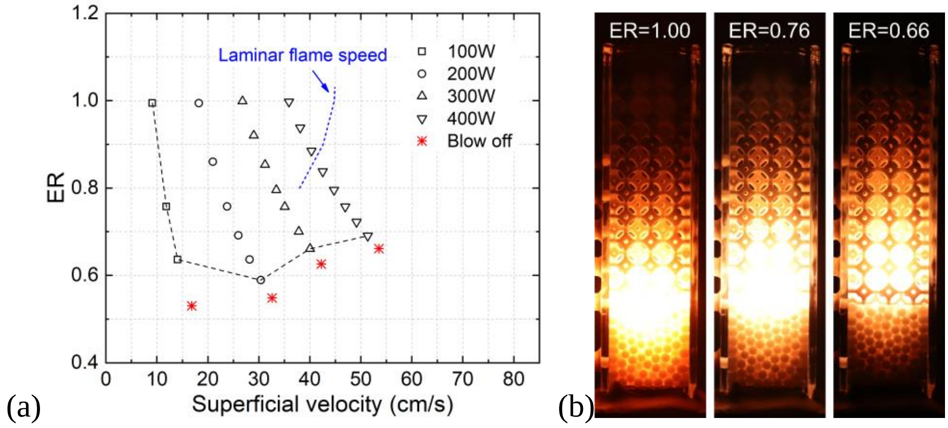

Fig. 3 (a) Range of stable conditions, (b) flame photographs at P_{in} =200W

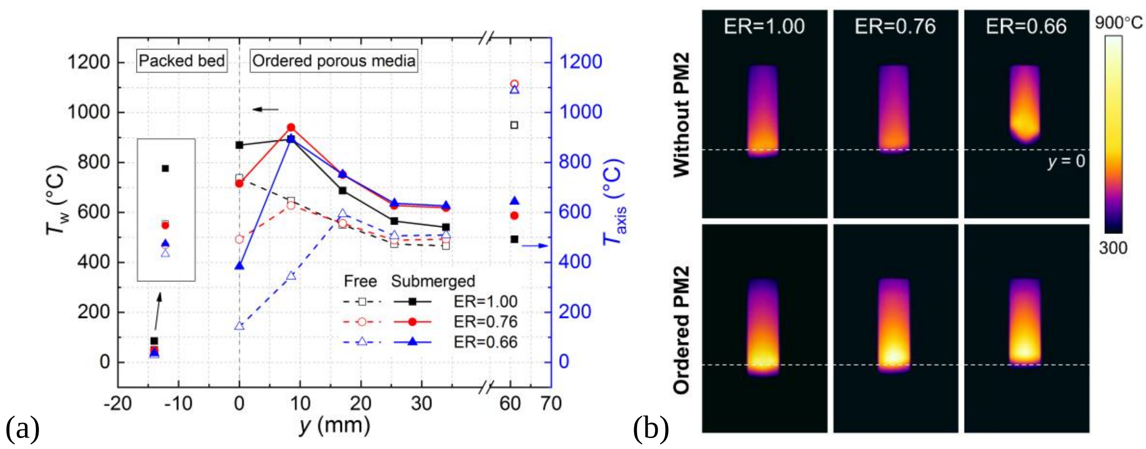

Fig. 4 Comparison of wall temperature distribution between conditions without PM2 and with PM2

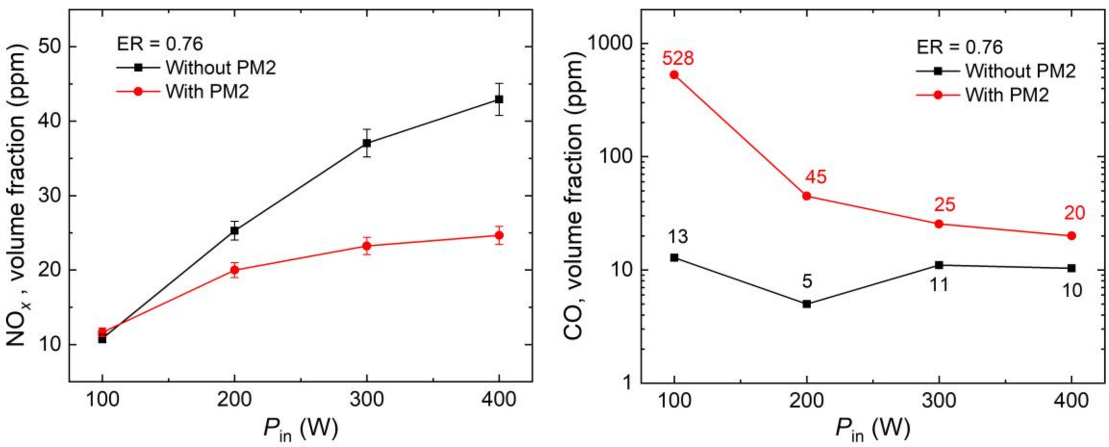

Fig. 5 Comparison of emissions between conditions without PM2 and with PM2

4. Conclusions

In this study, ordered porous alumina is manufactured via additive manufacturing technology, and combustion characteristics are studied. The flame can be stabilized in the porous media even when the flow velocity is greater than the laminar flame speed. The uniform porous media can improve the wall temperature and the uniformity of the cross-sectional temperature. The enhanced heat transfer and radiant heat loss by the porous media reduce the temperature of the reaction zone, which reduces the NOx content in the exhaust gas, but causes the CO content to rise, and the combustion process needs to be further optimized.

References

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