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Investigation of micro burner performance during porous media combustion for surface and submerged flames

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Abstract. Porous media combustion is considered to be one of the popular choice due to its tremendous advantages. Such type of combustion liberates not only super stable flame but also maintains emissions parameters below thresholds level. Present study incorporates reaction and preheat layer with discrete and foam type of materials respectively. Burner was made to run in ultra-lean mode. Optimum equivalence ratio was found out to be 0.7 for surface flame, while 0.6 during submerged flame condition. Maximum thermal efficiency was noted to be 81%. Finally, emissions parameters where recorded continuously to measure NOx and CO, which were under global limits.

1. Introduction

The natural gas industry is booming across the world for more than a decade. Saving combustible liquid fuel has become a key factor to both domestic and industrial market [1]. Additionally, major impact to any nation across the world is due to the super-fast depletion of fossil fuel. So, every possible attempts are made to save fossil fuels in some or the other way. One of the most popular area which consumes large amount of fuels is rigorous usage of burner which fulfills domestic needs [2-4]. Thus, porous medium burners (PMBs) can be taken a better option to adopt so that control over superfast depleting of fossils fuels is retained below threshold level. The major advantage of using porous materials inside burner housing leads to high temperature profiles and lower count in CO and Nox. Recent literature has repeatedly confirmed the PMB are it's the first choice to developed efficient burners [5-7]. Apart of being showing high thermal efficacy they do play vital role in lean flammability limits at higher burning rates [8-11]. Zhou, Huang [12] made at combustion performance and emission behaviors of a typical atmospheric induction gas stove and testing in both plain and plateau regions to evaluate the impact of altitude on combustion characteristics. While Wan, Gao [13] focused on temperature and flame behaviors under the tunnel ceiling for interacting flames. Interestingly, Zhong and Yu [14] and Singh, Hui [15] took butane as source of fuel to perform combustions and noted the surface and gas-phase reactions in microscale catalytic partial oxidation and soot formation in non-premixed counterflow flames respectively. Generally, two types of porous media are used inside the combustion zone namely, discrete and foam. Enabling porous media shall boost the origin of surface and submerged flame in more stable manner. A flame can be so called as submerged if there it is not visible to naked eye. While surface flame can be regarded as convention domestic stove flame.

2. Experimental setup

Fig. 1 indicates burner housing by highlighting major components. A complete layout of the system is as shown in Fig. 2 and actual setup in Fig. 3. Burner was divided into two layer namely reaction and preheat layer with each thickness of 10mm. Reaction zone was made with alumina spheres of 5mm radius. Supply of air-butane was fed from the bottom of the housing. Preheat layer was made of porcelain foam with 8 ppcm and a porosity of 84%. Thermocouple (K-type) was used to measure surface temperature (T1) while surface probe was used to for wall temperature at suitable locations (namely T2, T3, and T4). T1 was placed at mid of reaction zone, T2 at the junction between reaction and preheat layer while T3 at the mid of preheat layer. Thermocouples are connected to DAQ. Thermal images where taken by FLUKE thermal imager. Flow of air and butane was controlled by digital flow meter was measure L/min while emissions were captures using KANE-9106 QUINTOX Combustion Analyzer in ppm (parts per million).

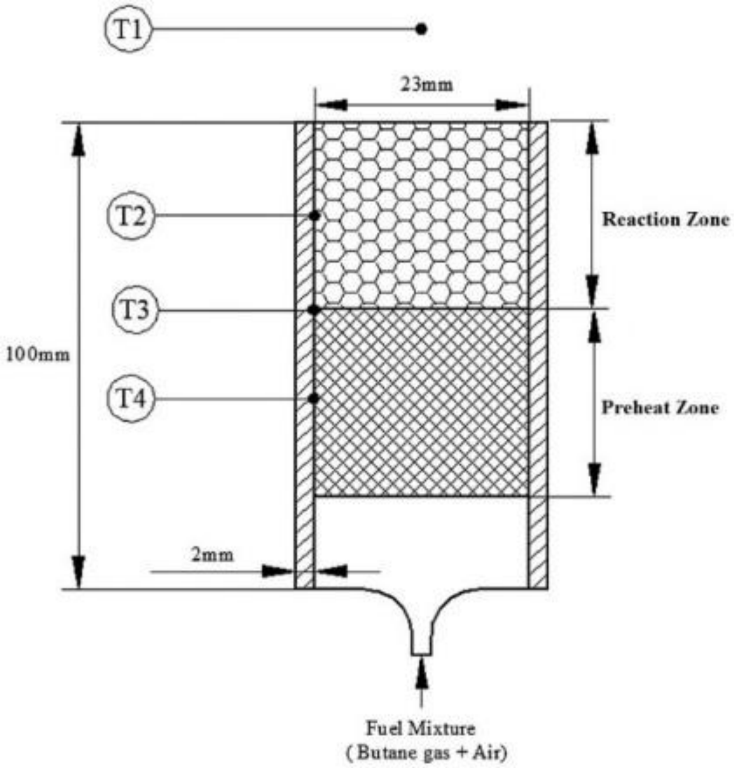

Figure 1. Sectional view of burner housing. (Not to scale).

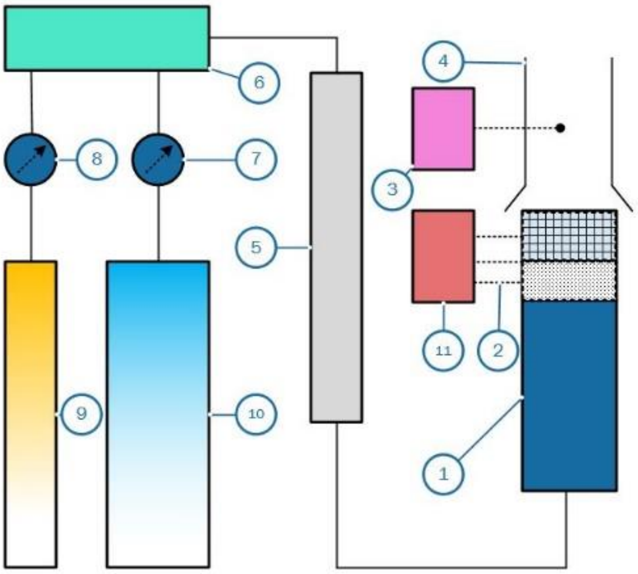

Figure 2. Layout of combustion system. (1) Housing, (2) Thermocouple, (3) Emission gas analyzer, (4) Gas conduit, (5) Mixing unit, (6) Pre-mix, (7) Air flow meter, (8) Butane flow meter, (9) Butane supply, (10) Air inject, (11) DAQ (Data acquisition system).

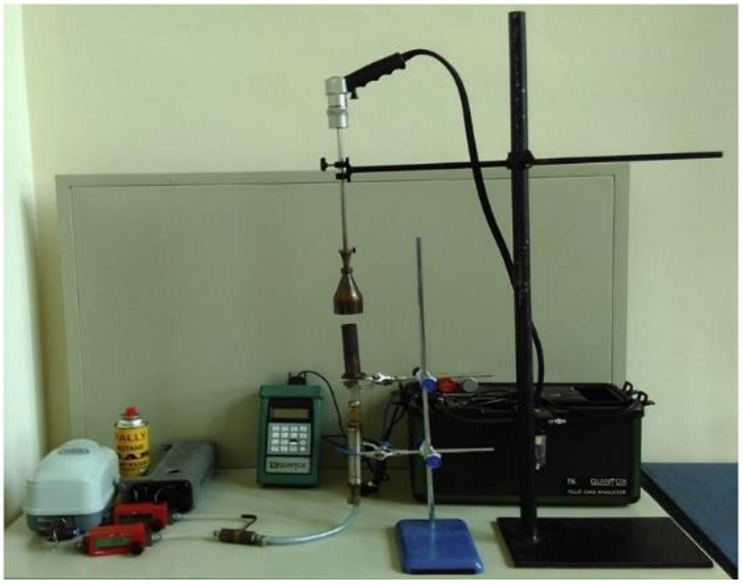

Figure 3. Experimental burner setup.

3. Analysis

Equivalence ratio (ER) is as shown in Equation (1), where the actual air–fuel ratio (Ma) and while stoichiometric air fuel ratio (Ms) for butane gas, was can be calculated by considering Avogadro's and Dalton's laws [16], which was computed a value of 30.95 with air at room temperature as shown in Table 1. Stable flame with minimum fuel consumption was obtained at 0.1 Lpm (litre per min). Trails were performed at room temperature. Maximum surface temperature was noted as 620°C at 0.7 ER, while maximum average temperature was recorded 165oC at 0.6 ER as shown in Fig 4 and 5. The possible reason of burner to undergoes surface or submerged flame mainly depends on availability of oxygen and surface area to perform combustion. Furthermore Fig. 6 indicate the actual photographic images at these respective ER. Thermal images are used to capture the temperature distribution at critical ER. With the help thermal imager generated photographic images indicate the sniped overview of temperature variation as shown in Fig. 7 and 8. Thermal efficiency was calculated at ER = 0.6 where in maximum surface flame the was recorded as 81%. Finally, with the help of certified gas analyzer, emitted emissions from the burner surface where fed to gas probe to measure NOx and CO. It was found out that emission where less than 1ppm since the minimum amount to detect the ppm for the utilized gas analyzer is 1pmm.

$$\mathrm{ER} = \frac{M_s}{M_\mathrm{a}} \tag{1}$$

Table 1. ER for butane and air flow rate.

Butane (Lpm)			0.1		
Air (Lpm)	3.1	3.4	3.8	4.4	5.1
ER	1.0	0.9	0.8	0.7	0.6

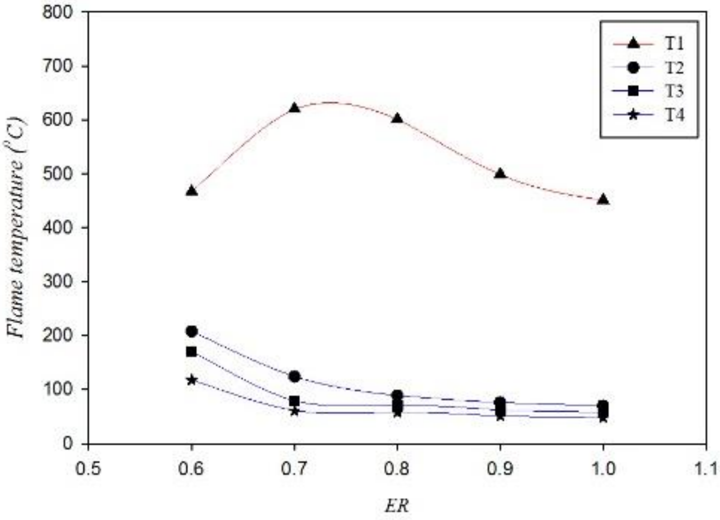

Figure 4. Flame temperature

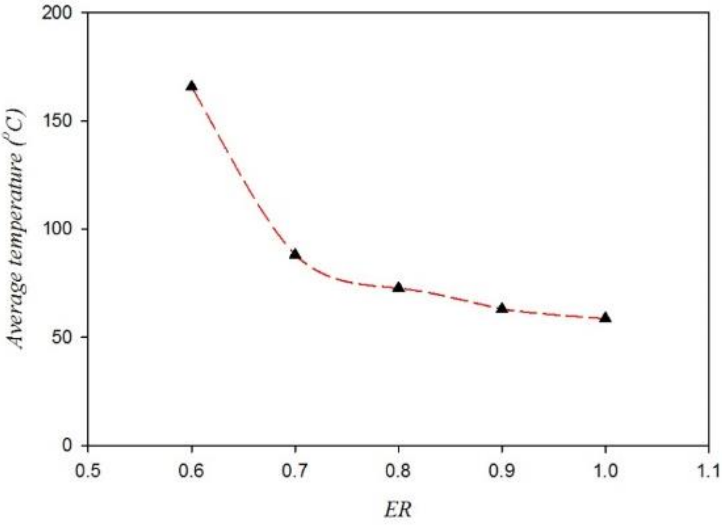

Figure 5. Average temperature

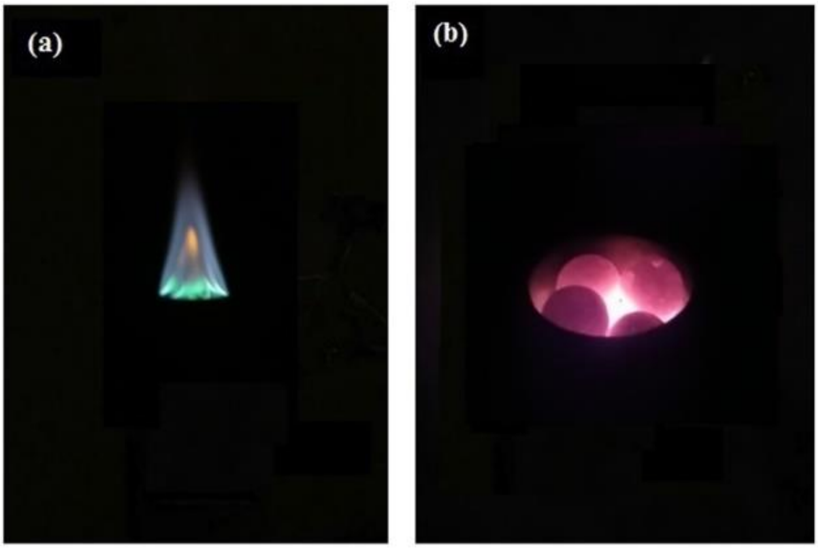

Figure 6. Actual photo

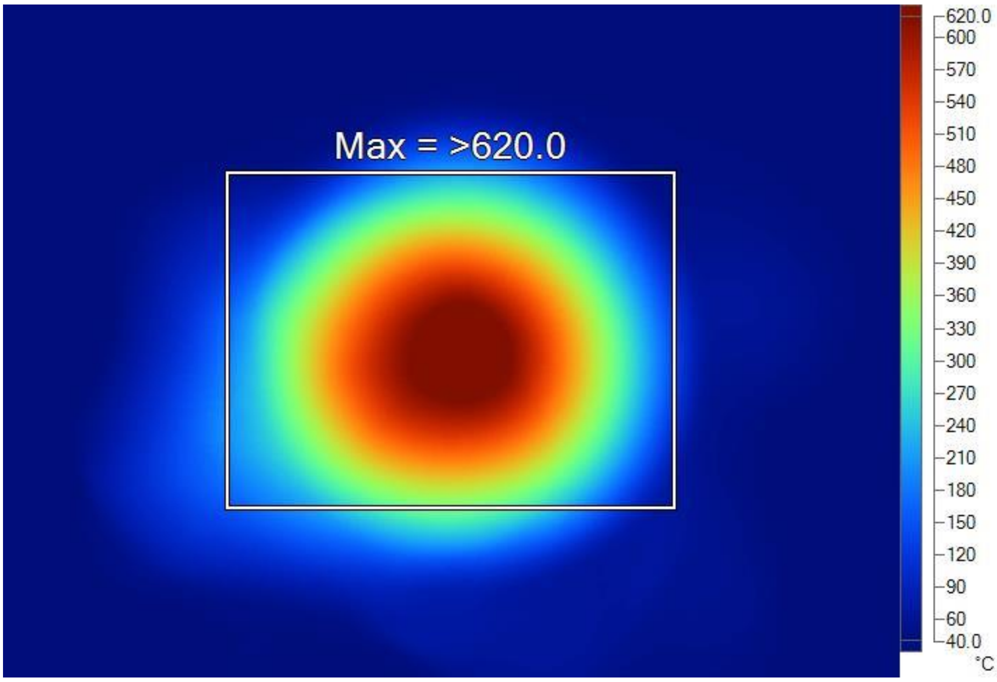

Figure 7. Thermal image (Top view).

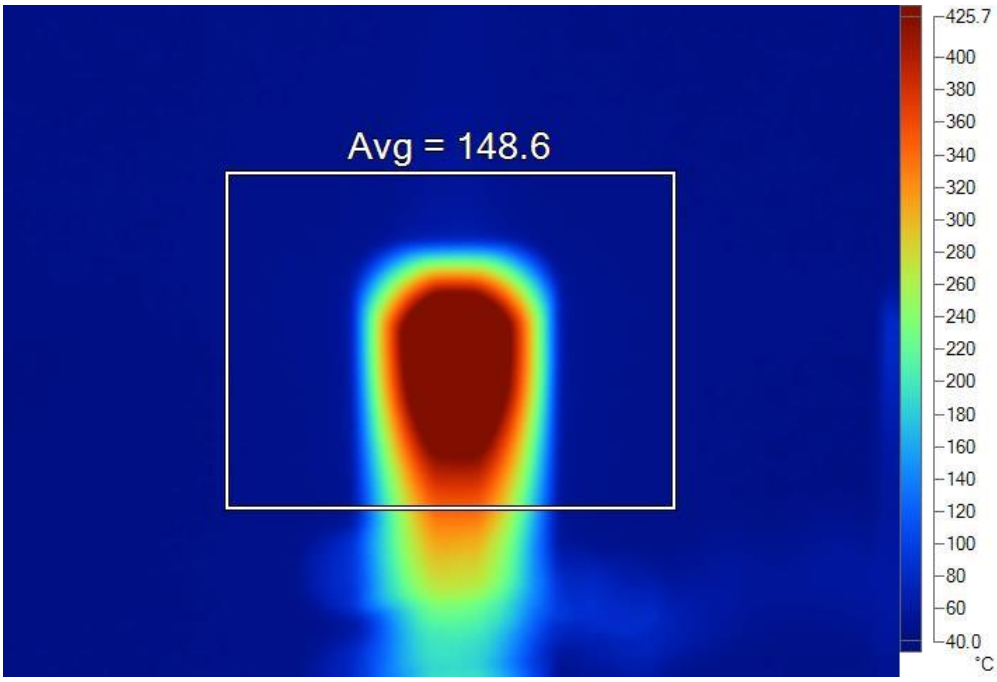

Figure 8. Thermal image (Side view).

4. Conclusions

Presented experimental work deal with clear bifurcation between surface and submerged flame based on ER. Predefined thickness of reaction and preheat layer was used to performed combustion. Optimum ER for surface flames and submerged flame are 0.7 and 0.6 respectively. Maximum temperature recorded at best performing ER was 620°C leading to thermal efficiency of 81%. Emission parameters such NOx and CO where less than 1ppm.

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