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Experiential study on temperature and emission performance of micro burner during porous media combustion

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Abstract. Addition of porous materials in reaction zone give rise to significant improvements in combustion performance. In this work, a dual layered micro porous media burner was tested for stable flame and emissions. Reaction and preheat layer was made up of discrete (zirconia) and foam (porcelain) type of materials respectively. Three different thickness of reaction zone was tested, each with 10, 20 and 30mm. Interestingly, only 20mm thick layer can able to show better thermal efficiency of 72% as compared to 10 and 30mm. Best equivalence ratio came out to be 0.7 for surface and 0.6 for submerged flame conditions. Moreover, emission was continuously monitored to detect presence of NOx and CO, which were under controlled limits.

1. Introduction

Saving of fossil fuels in any best possible way is prime factor for any nation to maintain its growth stable, hence utilization of fuel plays vital role. Consumption of byproducts of fossil fuels like LPG, butane, gasoline so on not only affect large scale industries but do interrupt domestic devices like burner and stove [1-3]. So both developed and developing nations prime moto is to come up with novel idea for improving the systems running of depleting fuels. In present scenarios super-fast demand has seen in liquid/gas fuels since large position of mankind depend on them to run their routine life like burner and stoves [4, 5]. Hence one of the advanced and promising agent can be used so called porous media (PM). Invent these materials in reaction zone of burner shall enhances show significant changes in combustion performances thus making porous media burner (PMB) efficient. The main two prime advantages of enabling PM inside the burner is to generate high temperature profiles (surface and walls) and lower the counts for emission[6-8]. Recent study form a decade has clearly indicated the importance of porous media in burners and their key role has proven to significant [9, 10]. Apart for these benefits, they do effect lean flammability limits at higher burning rates. Zhou, Huang [11] made study on gas supply pressure of the appliance and implies significant influence on actual heat input. Song, Wen [12] made an experimental work on premixed combustion of ultra-low calorific gas (LCG) in an axial and radial gradually-varied porous media burner with annular for heat recirculation and conveyed its importance. Pourhoseini [13] suggested a novel method to on pyrolysis technique for increasing intermediate soot particles concentration and enhancing radiative characteristics of natural gas flame. Park and Kim [14] worked on optimization of the Compact Submerged Combustion Vaporizers by first modeling the heat exchanger unit cell as porous media, then using the entropy minimization method. The porosity and equivalent particle diameter of the unit cell were independently controlled by varying the fin density and fin thickness or fin diameter, respectively and the entropy generation number was calculated numerically. In a typical bi layer porous media consist of top layer know was reaction layer where in combustions occur while lower region is treated as preheat layer. In the present study three different sizes of reaction layer are studied and optimum size thickness is suggested for the desired fuel mixture. In addition, best suited equivalences ratio (ER) was also shortlisted.

2. Experimental setup

Fig. 1 highlights typical insights of burner housing. While Fig. 2 and 3 indicates complete system layout and actual one to one photographic image of setup respectively. A micro burner was made with a cylindrical diameter of 22mm, thickness was 2mm and light was restricted to 100mm. Reaction zone was made of discrete PM of zirconia, with each ball was in spherical shape of diameter 10mm. The layer was tested for three sizes namely 10, 20 and 30 mm. While preheat layer was fixed at 10mm thick size of porcelain PM (foam type of 8 ppcm). A calculative amount of fuel mixture (butane and air) was fed from the base of burner housing to ensure ease flow inside preheat layer. In total four K type of thermocouple where enabled to capture temperature readings. Only one thermocouple places at surface of reaction zone (T1), mid of reaction zone (T2), junction of preheat zone and reaction zone (T3) and finally T4 was kept at mid of preheat layer. All the four thermocouples where wired to data accusation system to get digital readings of temperature profiles. To generate thermal images at various critical ER FLUKE thermal imager was adopted. Digital flow meters where connected across fluid flow tubes to monitor exact flow rates. A unit in terms of L/min was maintained for easy comparison of presented data with previous researchers. KANE-9106 QUINTOX Combustion Analyzer in ppm (parts per million) was used to sense emissions from burner chimney.

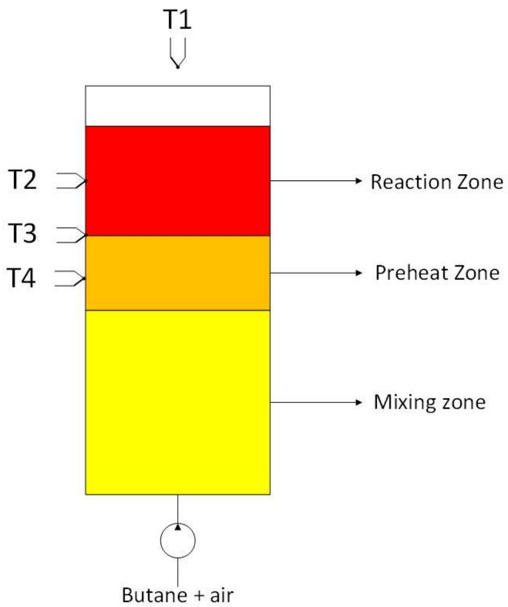

Figure 1. Sectional view of burner housing. (Not to scale).

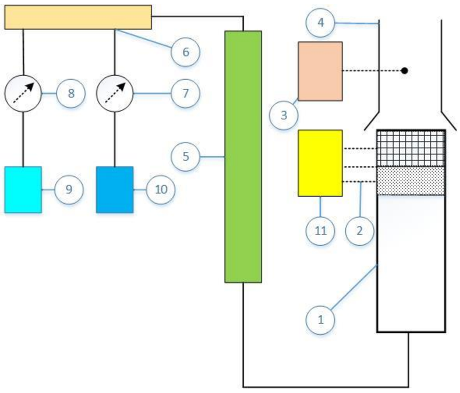

Figure 2. Layout of combustion system. (1) Housing, (2) Thermocouple, (3) Emission gas analyzer, (4) Gas conduit, (5) Mixing unit, (6) Pre-mix, (7) Air flow meter, (8) Butane flow meter, (9) Butane supply, (10) Air inject, (11) DAQ (Data acquisition system).

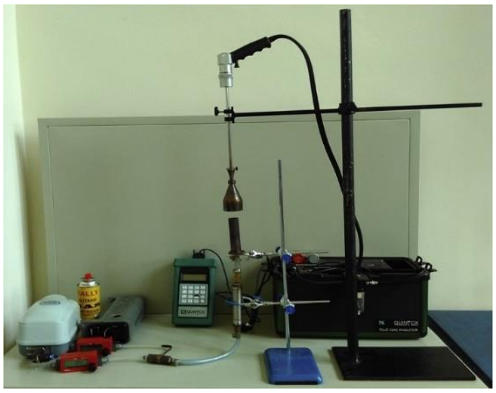

Figure 3. Experimental burner setup.

3. Analysis

In this experimental work a concept of ER is used since the combustion occurs is premixed type. Equation (1) indicates highlights the formulation used to calculate ER, where in actual air–fuel ratio (M_{act}) and while stoichiometric air fuel ratio (M_{sto}) for butane gas, was can be calculated by considering Avogadro's and Dalton's laws [5]. Table 1 indicates actual combination of air and fuel ratio used to get desired fuel mixture. Initially burner was made purposefully to run at low fuel contact so that burner can be made more efficient.

$$\text{ER} = \frac{M_{sto}}{M_{\text{act}}} \tag{1}$$

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

A process of trial and error has shown a minimum amount of fuel used to run the burner at safe and stable flame come out to be 0.1 Lpm (litre per min). Burner was made to run from stoichiometric ER to lean region. Interesting results were seen when all the three cases where plotted with a help of a graph as shown in Fig. 4. A maximum temperature value of 601°C was noted with reaction layer of 20mm thick while 505°C and 556°C where recorded at 10 and 30mm thick reactions zone. The possible reasons of getting such a differences is due to the availability of surface area to perform combustion, the pressure drop across reaction zone and preheat zone, and allowed ER [15, 16]. Burner was under surface flame condition when the ER was in the range between 1.0 to 0.6 and the it gives magnificent profile at ER=0.6 as indicate in Fig. 4. Incidence of submerged flame imitated soon ER cross 0.6 and tends to move towards 0.7. A completely submerged flame was seen with naked eye at ER=0.6. Furthermore, increase in ER led to back flash error thus made burner to shut down, its due to back force created in fuel mixture due to lack of oxygen supply to perfume combustion process[17, 18].

Fig. 5 indicates averaged wall temperature recorded over the wall of the burner, it can be seen that maximum recorded temperature was with 20mm thick layer. Thus optimum choice of selection would be 20mm rather than 10 and 30mm. Once the ideal choice of layer is made a thermal imager was used to get a temperature distribution on the wall of the burner as shown in Fig. 6. Value shown in Fig. 6

for average temperature from imager was 161.1°C, while actual value from DAQ was 165°C which can be acceptable. Thermal efficacy was also measured for critical ER for all the three cases. Maximum efficiency was calculated for 20mm thick layer, reaching up to 72%, while 59% and 66% were noted for 10 and 20mm thick reaction layer respectively. All the thermal efficiency was carried out at ER=0.6, since burner was at optimum performance at this ER. Finally, certified gas analyzer was added to setup to measure emitted emissions from the burner. Injected gasses where fed to gas tip to measure NOx and CO. It was found out that emission where less than 1ppm since the minimum amount the device can detect was 1ppm.

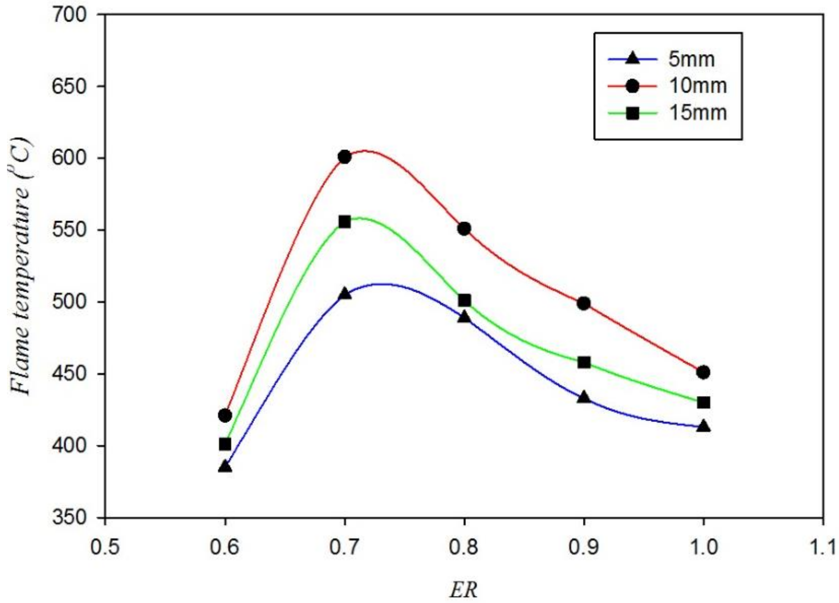

Figure 4. Surface flame temperature above the surface of reaction layer.

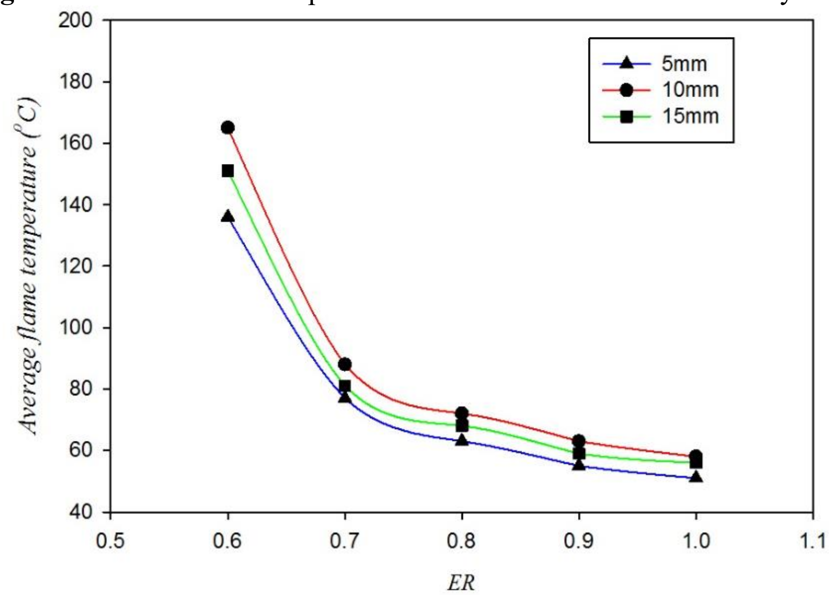

Figure 5. Average flame temperature at walls of the burner.

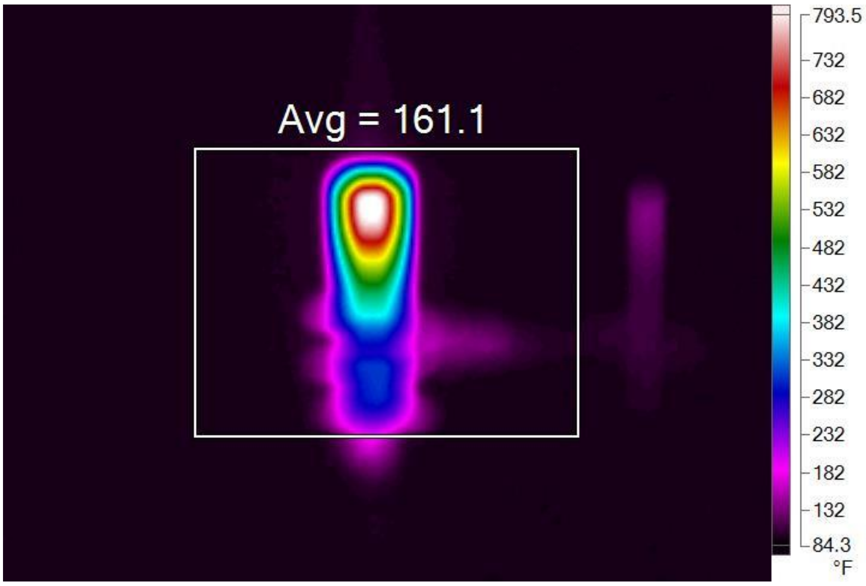

Figure 6. Temperature distribution image from thermal imager.

4. Conclusions

In this experimental work, a micro burner was made to undergo both surface and submerged flames. Burner was made to reach lean ER. Out of three predefined thickness of reaction zone, only 20mm could able to perform better results. Ideal ER for surface flames and submerged flame are 0.7 and 0.6 respectively. Maximum temperature that can be generated from this micro burner could reach up to 601^{o}C, thereby giving a thermal efficiency of 72%. Emitted emission results in low NOx and CO values.

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