Combustion analysis of porous radiant burner for commercial cooking applications

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Abstract. High efficiency and low efficiency were observed by using porous burner technology for commercial cooking. The whole research consists of survey of these three types of burners. Like burners diameter having convergent 100mm, straight 100mm and 80mm divergent shape burner. LPG is the fuel i.e. liquid petroleum gas is used in the all experiment. The two zones combustion and preheating zones comprise by a porous burner. Preheating zone having steel balls of width 6.5mm where combustion zone has Sic matric of 10ppi was used. 150mm is the constant altitude of three burners comprise of combustion zone and having equivalence ratio from 0.10-0.60. The range at which burner was operated 79% is the maximum efficiency analyzed for porous burner having dimensions like 100mm diameter at power equal to 0.84 kW and equivalence ratio (Φ) equal to 0.49.

1. Introduction

Country having a second biggest engrossment of LPG (Liquid Petroleum Gas) is subsidized as the government of INDIA pay out large sum of money that is Rs. 630. Rs. 630 is the subsidized value of LPG (liquid petroleum gas) cylinder of 14.21kg whereas Rs 800 for non-subsidized cylinder. Due to this (GOI) which we also called as government of India which facing large financial crisis as they are also taking the responsibility of the rest measure of the cash of the oil organizations. So, there is great need for finding alternative fuel so that there will be raise in the domestic burner thermal efficiency and also used as cooking purposes. so that we can reduce the economic burden from (GOI). Therefore, in present work (PBT) which is also called as permeable burner innovation are tried for LPG (liquid petroleum gas) terminated burner for cooking purposes. Combustion process required porous medium in porous burner technology. So that’s why it is also known as PRB that is porous radiant burner and (PMC) porous medium combustion. Preheating zone and the combustion zone are the two zones of (PMC) porous medium combustion the first zone i.e. combustion zone contains Sic ceramic matrix as well as in preheating zone there is low porosity to ignore resulting flash back and combustion flash back [17]. We can see a two-layer porous burner in diagram i.e. Figure1. In pre-heating zone, air fuel mixture first preheating whereas combustion take place in the combustion zone. Convection conduction and radiation method of warmth move heat is transmitted in all the direction. As comparisons with the domestic burners available in the market PMC having two important characteristics that is less emission and good thermal efficiency. And to raise the value of thermal efficiency and two deplete the emission of burner many of researches are working and for hose hold applications combustion review paper was represented by scientist known as Isabel Malico et al. [17] Porous burner is best suitable for commercial applications like cooking. For household applications the scientist Isabel Malico et al. [17] introduced an audit paper on a permeable media ignition.
A review paper that was presented by M. Amujeebu et al. [7] on different materials that utilize for porous burner. Research and development for PMC was reflected in their paper. P Muthukumar et al. [7] also produce a burner that is known as commercial cooking porous burner for LPG. 80%, 85%, 90% are different porosities at which burners were tested for different equivalence ratio and wattages ratios and wattages. In experimental set up, 80-90% porosity of Sic foam was used in the combustion zone as well as in preheating zone 40% porosity used. Efficiency was 10% which is good then the commercial burner available in INDIAN market and that achieved efficiency was 75%. Purna et al. [13] formed porous burner i.e.self-aspirating porous radiant. 3.0 m/s, 3.6 m/s and 0.4 m/s is the range of different velocities is basically get from the experiment conducted by Purna etal and two things were measured for the burner i.e. temperature distribution analysis and thermal efficiency. 64.6 % for velocity of 3.5m/s is the thermal efficiency 55.46% for gas speed 3.0 m/s and 36.42 % as gas speed 0.4 m/s.

A study was performed by Layriss Iral et al. [19] that was basically for the porous radiant burner which was actually on the induced air at high altitude and serving commercial applications. At three different powers that is (i.e. 370 kW/ 2m , 480 kW/ 2 m and 670 kW/ 2m ) burner was tested, with that we can likewise determine the warm productivity and outflows of the burner. 50% is the maximum thermal efficiency for the power 370kW/ 2 m was analyzed.

To check which one is gathering and furthermore estimated the warm productivity of the burner developed different various porous media burner was developed by Byeonghunet al. [12]. Metal fiber (MF), stainless steel fin (SF) and ceramic (CM) are three types of porous media which were basically utilized. Two different parameters were analyzed that is equivalence ratio and thermal efficiency of burner at different wattages and on the basis of that we can analyzed that MF burner have highest efficiency at 86.7% and $\Phi = 0.95$ at 25Kw whereas SF burner has efficiency 81.6% that is lowest and $\Phi = 0.80$ at 15Kw.

A self-aspirating porous burner that was built up by Wasan Yoksenakul et al. [4] is small scale enterprises and for medium one. Different practical work was analyzed at various power ranges as well as highest tower range from 21- 44 kW and variation of height was 75-125mm and for fuel LPG was used. We can analyze that there was decrease in thermal efficiency with increase in height with exception of the burner at 57.64% is the highest thermal efficiency.

For kerosene porous burner was developed and that was developed by Juga et al. [2]An experiment of porous insertion in kerosene pressure stove which is conventional one was performed by Sharma et al. [10]. The efficiency increased by 55% to 62% of stove by using porous insert. Porous radiant reticulated burner (PRRB) are designed for domestic application by Jaguiji and Sanitjai [2], and by compared to other burner the (PRRB) Porous radiant reticulated burner is much efficient in term of efficiency, emission characteristics and combustion stability.

Cooking application for LPG (liquid petroleum gas) another burner is developed by V. K. Patagi and P. Muthu et al. [14], and for this experiment was performed by changing the porosities, equivalence ratio and power. When we compare it with commercial burner its efficiency was 71% and 72% which was 6% and 7% better respectively then the commercial burner.

Figure 1. Schematic Diagram of A Two-Layer Porous Burner [2].
Application in which porous burner technology (PBT) can be used to raise the efficiency and depletion of the emissions optimized shape need to be observed basically all done in the literature survey. Preheating and combustion zones are the two zones of PMC preheating zones have metal balls of diameter 6.5mm which have low porosity and the another zone known as combustion zone which have SiC ceramic matrix another point of the concern is using low porosity in the preheating zone so that combustion would not take place and to avoid resulting flashback. Thermal efficiency and temperature distribution were investigated [20].

2. Experimental approach and procedures

There are two zones in the burner one is Combustion zone and another is Preheating zone. Combustion zone contain the SiC ceramics foam hold dimensions 10ppi and stiffness 25mm on the other hand preheating zone contains steel balls having width 6.5mm each. Two parameters thermal adaptability and also temperature distribution were determined for the two burners i.e. commercial and porous burner and with the help of water boiling test efficiency was calculated this is also shown in the above figure 1 Rotameter allowed LPG from cylinder of 14.21kg which is operated and then supplied to a burner. Rota-meter also aid to measure the fuel flow rate and flow testing two things are used like Aluminum pans along with the lid (0.5-1kg) of amount of water is required to filled the pan and at specific temperature i.e. (20-25°C). To check the repeatability quantity of water starting from 0.5-1 kg and varying a weight of water we can measured effect on efficiency with the help of weighing balance weight of pan with water can be calculated. The starting temperature and initial weight of the water and cylinder is calculated respectively.

![Figure 2](image-url)

**Figure 2.** (A) Schematic Diagram Experimental Setup (B) Experimental Setup (C) convergent Porous Burner (D) Divergent Porous Burner (E) straight porous Burner (F) Schematic Y-Shaped Mixing Tube.

When the flame becomes stable then burner is used on which the pan was kept after that the temperature of water rises till it reaches to 90°C, burner was turned off at this stage, after this calculation was made on the LPG cylinder weight again. It is crucial to note the time that the burner take increase temperature which is of water from T1 that is starting temperature to 90°C. For more accuracy of the experiment review are taken at any rate multiple times and also to conclude the final
result their unusual will be appropriated. According to a standard of IS 4246:2002[14]. Formula for calculating LPG (liquid petroleum gas) fired burner given by equation (1).

\[
\frac{100(W + P) (T_2 - T_1)}{m_f.CV}
\]

where \(W\) is the mass of water, \(m_f\) is the mass of the LPG expended and \(CV\) is the calorific estimation of LPG and \(P\) is mass of the pan along with lid made up of aluminum.

\[
\frac{\text{(air / fuel) actual}}{\text{(air/fuel) stoichiometric}}
\]

Actual one part of the ratio that is air fuel ratio tells about fuel consume for the actual combustion quantity of the air utilize to increase the desired temperature of water. With the help of rotameter air flow is calculated as well as we can get rate of actual air consumed for ignition as well as weighing balance help to measure fuel with the help of which we can get the rate of actual quantity fuel utilize for ignition or increasing water temperature. For this Stoichiometric fuel air ratio appropriated as 15.6 (used by V.K. Patang) [12-18]

3. Result and Discussion

Different equivalence ratio at which burner was operated was (0.10-0.60) whereas power wattages like (0.4-1KW). The result of temperature distribution and domestic burner adaptability and porous burner is studied in this section.

Varied to calculate the distribution of temperature to parameters is taken into consideration are as follow;

i). Equivalence ratio

ii). Air flow ratio

3.1. Temperature Distribution

Conventional burner and facial of PRB temperature have been measured with the help of K- type of thermocouple. (DAS) Data acquisition system (make Aberrancies TC - 900) was used to acquire the output of the thermocouple mostly 1 hour is the time at which burner were operated. Different equivalence ratio we get when the at different equivalence ratio i.e. (0.11-0.16) we get when all burners temperature were calculated. Different maximum temperature (1297-1505) attained by energy burner.

![Figure 3. Variation of Temperature W.R.T. Time (Minutes) of PorousBurner 100 Mm at Different Equivalence Ratio of convergent.](image-url)
At constant equivalence ratio the porous burner and increase in temperature as the time increase and max temperature attained by after 60 minutes that is 1462°C maximum temperature 13327°C when the temperature raise by 150°C then 5% increase in the mass fuel consumption at the equivalence of 0.11 and minimum temperature i.e. 1230°C toward the beginning of burning.

The difference in the porous burner surface temperature of 100mm diameter verses to air fuel ratio is shown by the figure 4. It was analyzed that as there is decrease in air to fuel ratio and it decline from 3.47 to 2.14 (38.2%). Then maximum raise of temperature was analyzed from 1227 to 1424°C. The temperature raise was less i.e. (1481 to 1490 °C) whereas the air fuel rate overload beyond 1.32 to 1.13 and this is because of saturation of heat in a porous medium.

![Figure 4. Variation of Temperature W.R.T. Air / Fuel Consumption of Porous Burner 100Mm Of Convergent](image)

In permeable disparate burner 90mm top diameter the temperature raised by some amount after 0f minutes as we increased the time. It was analyzed that 1502°C is the maximum temperature at equivalence ratio (Φ = 0.63). The mass fuel of expenditure increasing by 1.5 % and maximum temperature observed at equivalence ratio of 0.43 was 1442°C and that of 1227°C was least temperature at beginning of ignition.

![Figure 5. Variation of Temperature W.R.T. Time (Min.) of Porous Burner Divergent 80Mm at Different Equivalence Ratio.](image)

A porous divergent burner with dimension 90mm upper diameter with respect to air to fuel ratio and the its variation of surface temperature is shown by figure 6 with the decline of air to fuel ratio raise in fuel utilization we analyzed that there is raise in the temperature (1190 to 1380°C) is the maximum raising range of the temperature was seen when there is decline in the air / fuel rate from 2.2 to 1.9 (13.6%).
Figure 6. Variation of Temperature W.R.T. Air/Fuel Consumption of Porous Burner Divergent 80Mm.

Straight burner and facial of PRB temperature have been measured with the help of K-type of thermocouple. (DAS) Data acquisition system (make Aberrancies TC - 900). Was used to acquire the output of the thermocouple mostly 1 hour is the time at which burner were operated. Different equivalence ratio we get when the at different equivalence ratio i.e. (0.11-0.16) we get when all burners temperature were calculated. Different maximum temperature (1450-1485°C) attained by energy burner.

Figure 7. Variation of Temperature W.R.T. Time (Min.) of Porous Burner 100Mm straight at Different Equivalence Ratio.

Figure 8. Variation of Temperature W.R.T. Air / Fuel Consumption of Porous straight Burner 100 Mm.

Different temperature of the commercial burner v/s LPG fuel consumption is shown in Figure 8. Can be analyzed in fig 9 and with the raise in the fuel utilization 1230°C an is the most extreme temperature achieved by the commercial burner and 0.028 gm/sec consumption is required for this process.
requires. Another point we also analyzed that the higher estimation of greatest temperature that is in the range of (6.89 – 20.94 %) of porous burner and all this analyzed this for same fuel consumption.

![Graph of Temperature vs. LPG Fuel Consumption](image1)

**Figure 9.** Variation of Temperature W.R.T. LPG Fuel Consumption (Gm/Sec) for porous burner and without porous burner.

### 3.2. Thermal efficiency

Thermal efficiency of porous burner as well as commercial burner is shown by fig 10. If we take comparison between porous and other burner, we can analyze that the porous burner of diameter 100mm has maximum efficiency. When there is a constant power of 0.6kW. We can analyzed that porous burner of 80mm diameter commercial burner as well as divergent burner all have thermal efficiency less than the 80mm porous burner they have thermal efficiency of 15.67 %, 22.13 % and 30.32 % respectively and the porous burner of width 150mm having maximum efficiency of 78.58 % at equivalence ratio of 0.48 and at power 0.84Kw.

![Graph of Efficiency vs. Power](image2)

**Figure 10.** Variation of Efficiency of Porous and without porous Burner Vs. Power(Kw).

### 4. Conclusion

The porous burner and divergent shape of burner taken for an experimental analysis and their thermal efficiency were calculated and differentiate with commercial burner.

Following are the conclusions:

- 65 % is the higher capability of commercial burner.
- Porous burner has the thermal efficiency more than commercial burner that is 7 8.58 % and it is 13.5 % more than the domestic burner.
- 62.7 % is the maximum efficiency of porous burner 80mm that is 8 % more than the commercial burner.
• Porous burner which is divergent shape has maximum efficiency of 51.78%.
• 1462°C which is maximum temperature at 0.16 which is equivalence ratio (Ø) is of porous burner with diameter 100mm.
• 1380°C which is maximum temperature at 0.47 which is at equivalence ratio (Ø) of 80mm diameter porous burner.

After testing porous burner experimentally for the commercial applications and we can conclude that the thermal efficiency of porous burner with 100mm diameter was 78.58% was highest among the entire burner. At the same time, fuel consumption. In future the computational analysis of work will be done.

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