Development of Porous Radiant Burners for Domestic LPG Cooking and Industrial Applications

Dr. P. Muthukumar
Associate Professor
Department of Mechanical Engineering
Indian Institute of Technology Guwahati
Guwahati - 781039, INDIA
Email: pmkumar@iitg.ernet.in
About IITG

- Located in the Gateway of North – Eastern Part of India
- Beautiful campus among other IITs. Located on the river bank on Brahmaputra[Yarlung Tsangpo-Siang-Brahmaputra-Jamuna]. Campus is surrounded by many Hills and Lakes.
- Campus size about 700 acre.
- 8 Engg and 4 Science Departments. About 6000 students, 425 faculty and 500 supporting staffs.
- Few thousands of migratory birds, wild cats, etc.
Outline of Presentation

- Indian LPG consumption pattern
- Concept of porous medium combustion (PMC)
- Advantages of PMC
- Development of Porous Radiant Burner (PRB)
- Performance testing
- Concluding remarks
India is the fourth largest consumer of LPG in the world. India is not self-sufficient in LPG – has to import a huge amount of LPG.

**LPG: Propane – 57-60% + Butane – 40- 43%**

**Demand vs Indigenous Production**

- **India: ≈1.2 billion**
- **Number of LPG Consumers:** 246,692,667
Government provides a huge amount of subsidy ~ $7 Billion

For consumer too the price is increasing

From $16 to $6.8
## Conventional LPG Cooking Stoves

<table>
<thead>
<tr>
<th>Burner Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nikitsa Burner</td>
<td>Regular Burner</td>
</tr>
<tr>
<td>Regular Burner</td>
<td>Side flame burner</td>
</tr>
<tr>
<td>Sunflame Burner</td>
<td>BPL burner</td>
</tr>
<tr>
<td>Super flame Burner</td>
<td>Aluminum base burner</td>
</tr>
</tbody>
</table>

**Low thermal efficiency:** 60 – 65%

**High emissions:***

- **CO:** 400 – 1050 mg/m³
- **NOx:** 160 – 220 mg/m³
Flame propagation for:

Pecklet number $P_e = \frac{u_L \rho c_p d_m}{k} \geq 65$

where

- $u_L$: laminar flame velocity
- $d_m$: equivalent porous cavity diameter
- $c_p$: Heat capacity of gas mixture
- $\rho$: Density of gas mixture
- $K$: Thermal conductivity of gas mixture

Solution: LPG/kerosene stoves with porous radiant burner
LPG stoves with conventional burners

Free flame combustion NOT efficient

Combustion in porous media is efficient

Solution: LPG/kerosene stoves with porous radiant burner
Design details of Porous Radiant Burner

EXPERIMENTAL SET UP

Muthukumar and Shyamkumar, Fuel, 2013;112:562-566
EXPERIMENTAL SET UP: A Picture Showing Red Hot PRB

Flow meter for Air

Flow meter for LPG

Red Hot PRB
Photographs of PMB and the conventional domestic burner

Conventional burner

Porous radiant burner
\[ \eta_{th} = \left( \frac{m_w C_{pw} + m_v C_{pv}}{m_f \cdot CV} \right) \left( T_2 - T_1 \right) \times 100 \]

Conventional Burner
- Efficiency: 50-65%
- CO Emission: 400 to 1050 mg/m$^3$
- NOx Emission: 160 to 220 mg/m$^3$

Equation:

\[ \phi = \frac{(A/F)_{Stoich}}{(A/F)_{Actual}} \]

- Combustion Zone: SiC (different porosity) and ZrO$_2$ (90%)
- Preheating Zone: Alumina Balls and Alumina Matrix (40%)
- Equivalence ratio $\phi$: 0.5 – 0.7, Wattage: 1.3 kW – 1.7 kW.

Muthukumar and Shyamkumar, Fuel, 2013;112:562-566
The flue gas sampling was done according to the IS: 4246:2002

A portable flue gas analyser (TESTO) was used for measuring CO and NOx emissions.

### Conventional Burner

- **CO Emission**: 300 to 1050 mg/m³
- **NOx Emission**: 4 to 220 mg/m³
- **Efficiency**: 50-65%

### PRB with 90% porosity

- **CO Emission**: 10 to 140 mg/m³
- **NOx Emission**: 0.1 to 0.9 mg/m³
- **Efficiency**: 70-75%

**Dr. P. Muthukumar, Mechanical Engg., IIT Guwahati, October 2014**
Axial Temperature Distribution

- Combustion zone (TC)
- Preheating zone (TP)
- Down side of the wire mesh (TD)
- Interface of the two zones (TI)

- Temperature at TI showing higher than any other regions

Max. TI = 1170 °C

90% porosity burner (PPZ – Alumina matrix)
A series of experiments were carried out at wide range of ambient temperatures from 13.5 °C to 30 °C.

Thermal efficiency of the PB is directly proportional to ambient temperature.

The maximum thermal efficiency was found to be 75% at 30 °C and 63% at 13.5 °C.
At the thermal load of 10 kW, the PRB yielded the maximum improvement in thermal efficiency of about 34.3%.
The newly developed porous radiant burner (PRB) for LPG cooking stoves has been found to have the maximum thermal efficiency of ~ 75% which is 15% higher than the conventional burner.

Measured CO and NOx emissions of the PRB were in the range of 25-150 mg/m³ and 0-2 mg/m³. While, the respective values of the conventional burners are in the range of 400-1100 mg/m³ and 75-260 mg/m³.

In terms of both thermal efficiency and emissions, the PRB has been found to be better than its conventional counterparts.

Compared to a conventional burner, the newly developed PRB saves about 2 kg of LPG per cylinder (14.5 kg capacity).
Required modifications before commercialization

- PRB, the combustion is happening completely within the porous matrix. The entrained air is NOT enough to give flameless combustion.

- The porous matrices in the preheating zone and combustion zone added to the flow resistance.

- To overcome the flow resistance offered by the porous matrices, the air was supplied at \(\approx 1.2\) bar.

- For domestic cooking, it CANNOT be commercialized unless it works without any external air supply.
PRB Without External Air
- Modified pressure regulator, nozzle diameter and mixing chamber.

- Achieved flameless combustion with natural entrainment.

- Achieved 73-74 % thermal efficiency and less emissions

- Showed stable operation

- Power modulation is being investigated.
Brief Biography: Dr. P. Muthukumar


Teaching / Research Experience
Associate Professor: IIT Guwahati, from 9-01-2010 onwards
Assistant Professor: IIT Guwahati from 27-01-2006 to 8-01-2010
Senior Project Officer: IIT Madras from 1-07-2004 to 23-01-2006

Student Guidance
PhD: 3-Awarded; 2-Thesis submitted; 2-Advance stage; 4-Ongoing.
M.Tech: 25-Completed; 3-ongoing; B.Tech: 15-Completed; Project staffs: 4

Research Contributions
Int Journals: 40 + 10 Communicated (citation = 431)
Int Conference / workshops: 56
National Conference: 6
Patents: 1 (Patent Number: 173/KOL/2013)
Completed Projects: 4 Sponsored (63.35 L) + 3 Consultancy (7 L)
Ongoing Projects: 1 Sponsored (128 L)
Projects under evaluation: 2 sponsored (337 L) + 1 consultancy (36 L)

Awards / Fellowships received
• Received DAAD Research Fellowships 3 times (2008, 2010, 2012)
• Young Engineer Award -2012, from Senior Engineers Forum of Greater Guwahati
• Commission Member from India to work with the International Institute of Refrigeration (IIR)
• Represented India in Spain at Indo-Spain joint Workshop on Renewable Energy during March-11
• IEI Young Engineer Award-2010 in Mechanical Engg., from Institute of Engineers (India)
• DST-DAAD Project based Fellowship- 2000.
Thanks for your kind attention