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Thermal Analysis of Domestic Gas Burner by Design Optimization of Burner Heads on CFD Fluent

Devendra Veer Vikram Shahi[1], Vardan Singh Nayak[2] Prashant Paraye[3]

[1]M.Tech Scholar, Department of Mechanical Engineering, Vidhyapeeth Institute of Science and Technology,
[2]Assistant professor, Department of Mechanical Engineering, Vidhyapeeth Institute of Science and Technology,
3Lecturer, CIPET (Central Institute of Plastics Engineering & Technology), Bhopal, India.

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Abstract - *Liquefied petroleum gas (LPG) is the most commonly used cooking fuel in India and many other countries on the globe. LPG cook stoves are comparatively very efficient, clean, need low maintenance, and are portable too. Because of these benefits and the subsidy provided by the Indian Government for LPG cylinders, the use of these burners for cooking purposes has become popular in urban and sub-urban India.*

In the initial stage, different geometries and designs of LPG stovetops are tested for their parametric influence on thermal performance and emissions. It was observed that, as per literature, no work has been done on the nozzle angle of burner holes. We proposed three different burner hole configurations at optimized angles as per base paper. We performed ANSYS fluent analysis for this burner configuration to find out the best thermal efficiency of the proposed design. Thermal efficiencies of these burners are increasing up to a certain power range and then decreasing sharply with an increase in firing rate. CO and NOx emissions are decreasing with the increase in thermal efficiency. Thermal efficiency of the burners varies with material, pattern, number and size of holes on the burner tops. It was observed that swirling of flame increases thermal efficiency compared to flat flames and a reduction in NOx and CO is also observed compared to flat flames.

***Key Words**: Liquefied petroleum gas (LPG), burners, cook stoves, performed ANSYS fluent analysis, Thermal efficiency, firing rate*

1. INTRODUCTION

1.1 Energy Demand and Crisis

In developing countries like India, the rural energy crisis was followed by a scarcity of cooking fuels, especially firewood. Cooking is the most energy-intensive operation in the village energy matrix, according to studies conducted in various parts of India [2, 3]. Even at the national level, the domestic market, which is dominated by cooking energy consumption, consumes 40% of total energy [4]. Aside from energy considerations, the type of cooking fuel used, its consistency, availability, and accessibility, as well as the cooking device used and its efficiency, all affect women's quality of life, especially in rural areas. Despite the fact that cooking energy plays a dominant role in the Indian energy landscape, little has been done to systematically analyse the cooking energy options available to potential consumers in terms of quality, economics, and services given.

1.2 Combustion System

The conversion of thermal energy from a combustion process to a load used in cooking applications relies on four components. The burner is one part that burns the fuel with an oxidizer to generate heat. Another factor is the load, which has a significant impact on how heat is transferred from the burner to the load. The third component in cooking is the flow control unit, which controls the rate of fuel and oxidizer flow, and the fourth component is the fuel.

1.3 The Burner's Configuration

A burner is a system that burns fuel and uses an oxidizer to transform the fuel's chemical energy into thermal energy. A burner may be categorised as an industrial or commercial heating burner or a domestic cookstove, depending on the end usage. In addition, the burner may be used in flameless or flame mode. Depending on whether the fuel and oxidiser are mixed before combustion or the oxidiser is supplied during combustion, a burner can be premixed or diffused. A domestic cook stove is a form of partially premixed induced air burner that is now used for flame heating. As a result, several factors affect the design of a burner, including material, burner structure, fuel characteristics and velocity, air fuel ratio, mixing tube geometry, load distance from the burner port, and port geometry, among others.

1.4 Contemporary Burner Design Issues

Until a decade, the burner designer was mainly concerned with efficient fuel combustion and efficient heat energy transfer to the load. As environmental regulations have become more strict, it has become essential to consider emissions from burners while designing to save fuel. In certain cases, lowering emissions and increasing combustion efficiency are mutually exclusive. The amount of NOx emitted during fuel combustion is proportional to the temperature. The peak temperature of the flame during stoichiometric air-fuel combustion is very high, so thermal NOx formation is higher. Since fuel-rich or fuel-lean areas are less conducive to NOx formation than close stoichiometric zones, using the staging technique to minimise NOx emissions lowers peak temperatures in the primary flame region. Since thermal NOx is proportional to the temperature of the gas, even small decreases in the peak flame temperature will substantially reduce NOx emissions. Higher flame temperatures, on the other hand, limit radiant heat transfer from the flame because radiation is proportional to the absolute temperature of the gases. Another issue with staging is that it can increase CO emissions, which indicates incomplete combustion and reduces combustion efficiency.

1.5 Research Objective

In the initial stage, different geometries and designs of lpg stove tops are tested for their parametric influence on thermal performance and emissions. It was observed that as per literature no work has been done on nozzle angle of burner holes. We proposed three different burner hole configuration on optimized angles as per base paper .We performed ANSYS fluent analysis for this burner configuration to find out best thermal efficiency of proposed design. Thermal efficiencies of these burners are increasing up to certain power range and then decreasing sharply with increase in firing rate. CO and NOx emissions are decreasing with the increase in thermal efficiency. Thermal efficiency of the burners are varying with material, pattern, number and size of holes on the burner tops. It was observed that swirling of flame increases thermal efficiency compared to flat flames and a reduction in NOx and CO is also observed compared to flat flames.

2. Methodology

CAD Modeling

The creation of CAD models using CAD tools to create the geometry modeling NX part / assembly

Meshing

Concerning the microscopic balances, notice that all the governing equations are differential equations with a continuous solution along the space. The system discretization is the way to assign the mathematical model to a finite element of the system, transform those differential equations in algebraic equations, and then, solve the system. That is called finite element method.

Pre-processing:
With the increase in mesh size (increase no. Element), CFD analysis speed decreased but increased accuracy. Concerning the microscopic balances, notice that all the governing equations are differential equations with a continuous solution along the space. The system discretization is the way to assign the mathematical model to a finite element of the system, transform those differential equations in algebraic equations, and then, solve the system. That is called finite element method.

Type of Solver:
Select a solver for the problem of pressure-Based and density based solver.

Physical Model:
Select the required physical models for problems
Viscous model
Radiation model
Species transport: non-premixed model

Boundary conditions
Set the different inlets, outlets and limits of the system.
Solution:
Methods of solution
Choosing a solution method to solve the problem that the first order, second order
Solution Initialization: initialized solution to obtain an initial solution to the problem.

Post processing
To view and interpretation of results. The result can be viewed in various formats: chart, values, animation etc.

3. RESULTS

Study of NOX

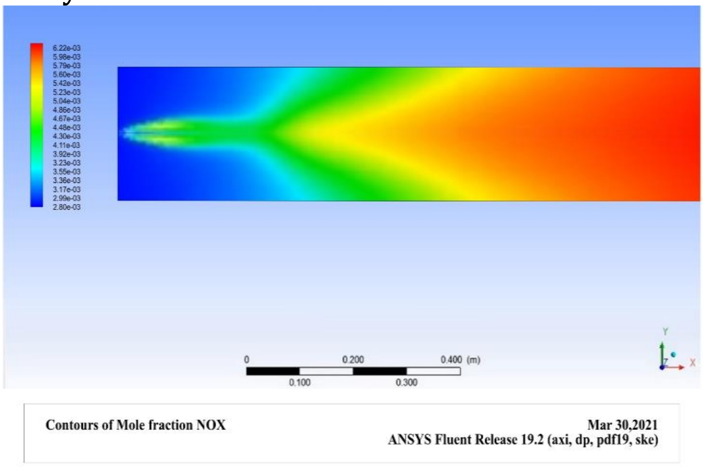

Figure 5.1: Contours of mole Fraction of NOX at D= 0.8 mm

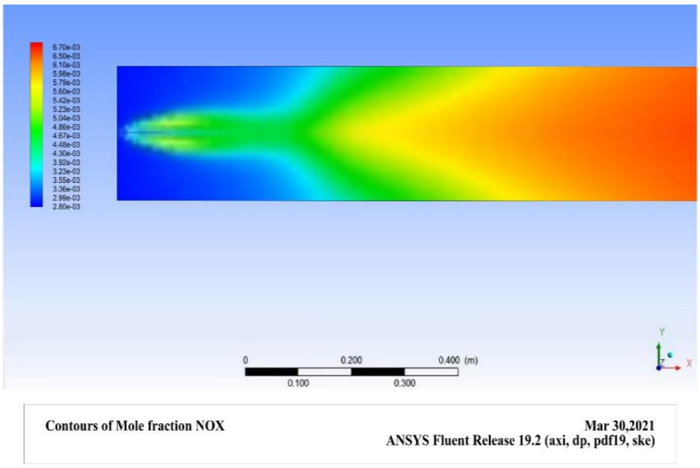

Figure 5.2: Contours of mole Fraction of NOX at D= 1.0 mm

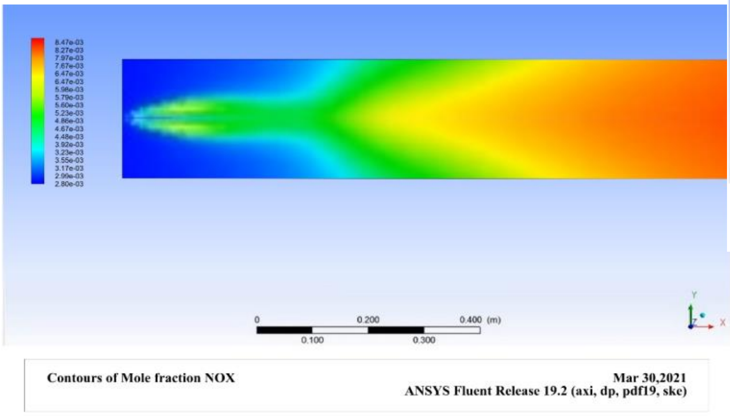

Figure 5.3: Contours of mole Fraction of NOX at D= 1.2 mm

Table 5.1: Study of NOX (Mass fraction after combustion)

Diameter of nozzle {mm)	Contours of Mole Fraction of NOX
D=0.8	6.22e-003
D=1.0	6.70e-003
D=1.2	8.47e-003

Study of O2

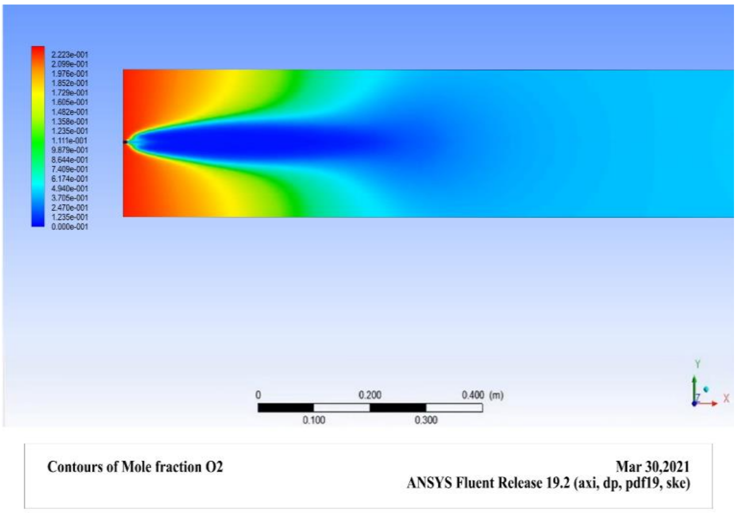

Figure 5.4: Contours of mole Fraction of O2 at D= 0.8 mm

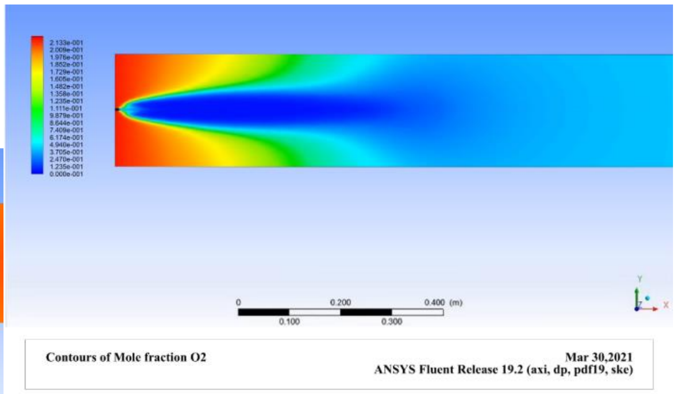

Figure 5.5: Contours of mole Fraction of O2 at D= 1.0 mm

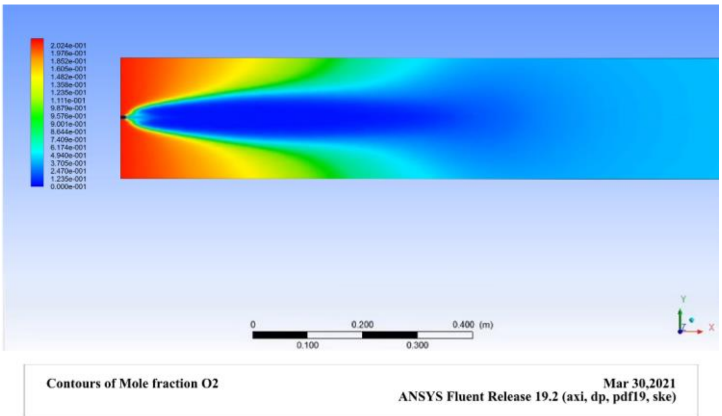

Figure 5.6: Contours of mole Fraction of O2 at D= 1.2 mm

Table 5.2: Study of O2 (Mass fraction after combustion)

Diameter of nozzle {mm)	Contours of Mole Fraction of O2
D=0.8	2.223e-001
D=1.0	2.133e-001
D=1.2	2.024e-001

Study of H2O

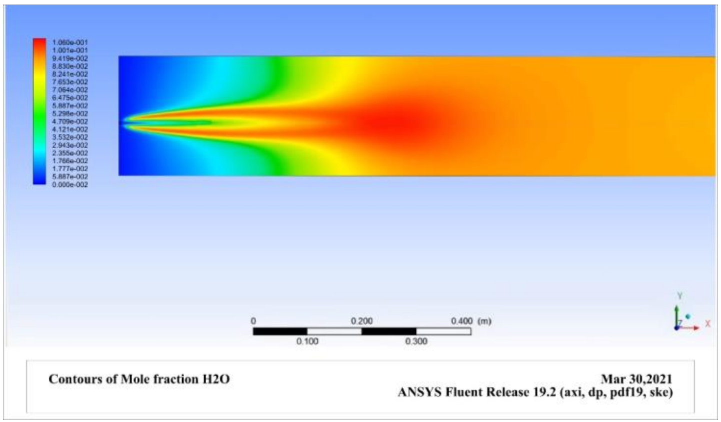

Figure 5.7: Contours of mole Fraction of H2O at D= 0.8 mm

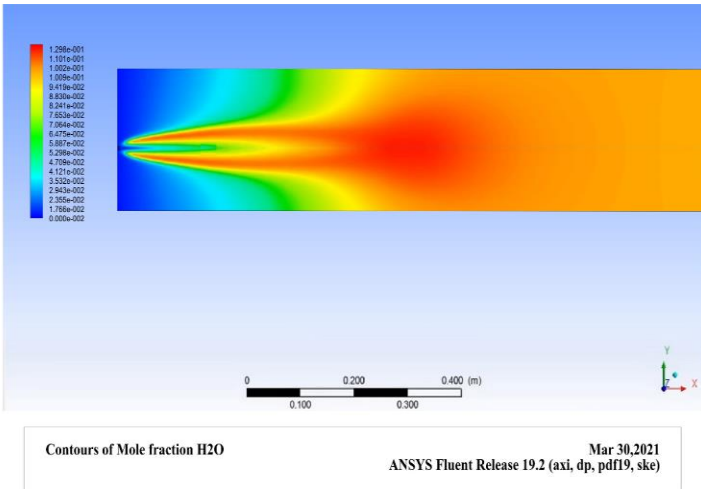

Figure 5.8: Contours of mole Fraction of H2O at D= 1.0 mm

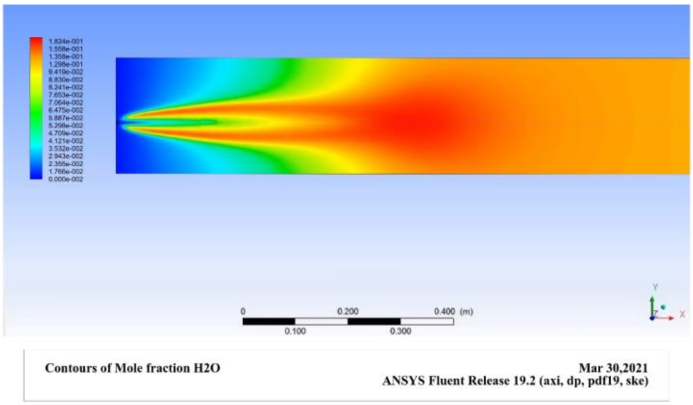

Figure 5.9: Contours of mole Fraction of H2O at D= 1.2 mm

Table 5.3: Study of H2O (Mass fraction after combustion)

Diameter of nozzle {mm)	Contours of Mole Fraction of H2O
D=0.8	1.060e-001
D=1.0	1.298e-001
D=1.2	1.824e-001

Study of Velocity

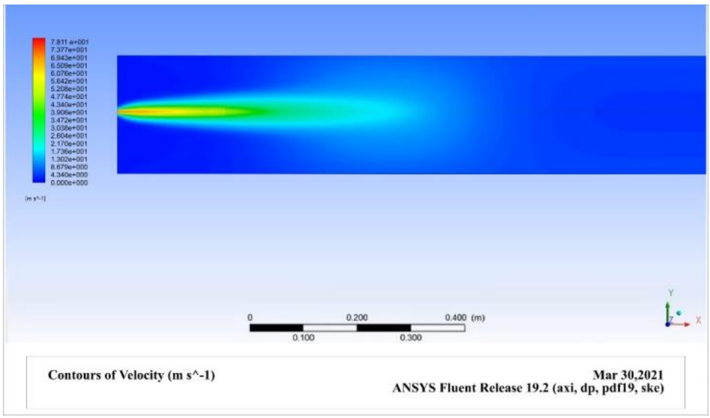

Figure 5.10: Contours of velocity (m/sec) at 0.8 mm

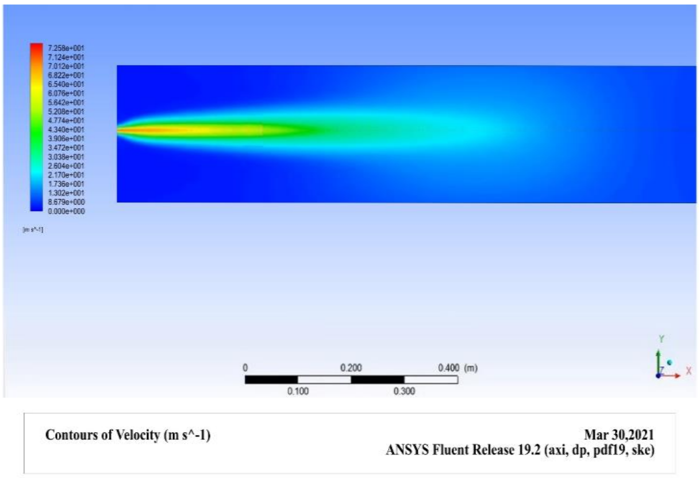

Figure 5.11: Contours of velocity (m/sec) at 1.0 mm

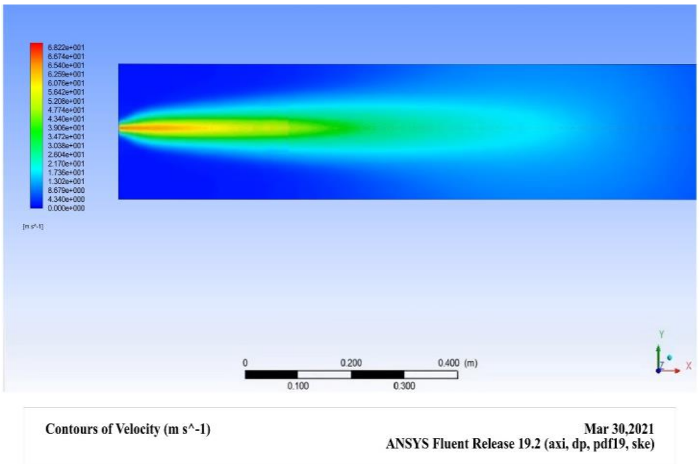

Figure 5.12: Contours of velocity (m/sec) at 1.2 mm

Table 5.4: Study of velocity (after combustion)

Diameter of nozzle {mm)	Contours of Velocity
D=0.8	7.811e+001
D=1.0	7.258e+001
D=1.2	6.822e+001

Study Of temperature

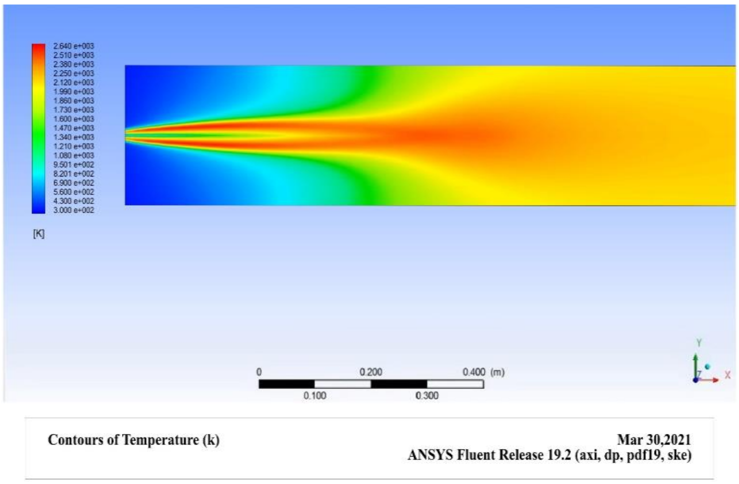

Figure 5.13: Contours of Temperature (k) at 0.8 mm

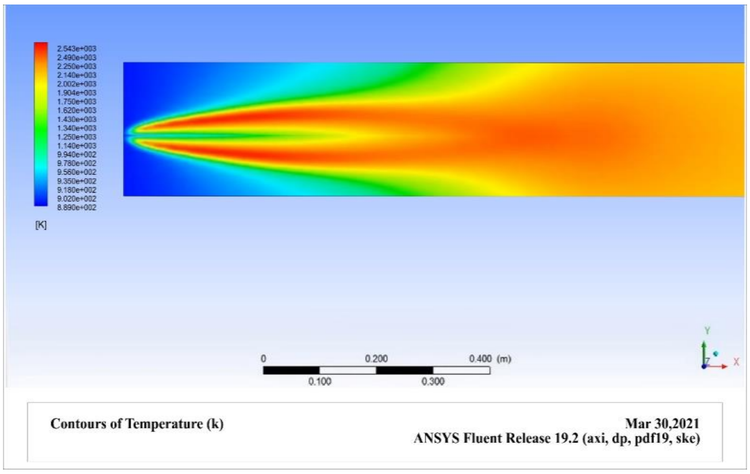

Figure 5.14: Contours of Temperature (k) at 1.0 mm

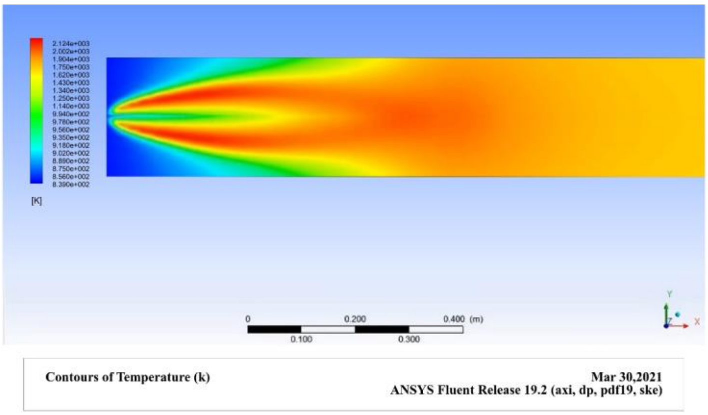

Figure 5.15: Contours of Temperature (k) at 1.2 mm

Table 5.5: Study of Temperature (after combustion)

Diameter of nozzle {mm)	Contours of Temperature
D=0.8	2.604+03
D=1.0	2.543+03
D=1.2	2.124+03

4. CONCLUSIONS

After all, the work done, the results show interesting results. It is clear that the changing the circular geometry in to nozzle shape significant effect on thermal efficiency and the NOx formation.

First, the reducing angel of nozzle produces a direct effect in the temperature profile of the system. It increases the peak temperature and also the average temperature of the system, what implies a reduction of the thermal NOx (which are the main contributors to the total NOx as can be observed from the profiles).

Secondly, as can be observed in the profiles, the concentration of both radicals [O2] and [C3H8] is optimized by reducing the nozzle angel which influences the equilibrium reactions implied in the formation of NO and NO2.

Another interesting conclusion is that, velocity and pressure profile is also been optimum at some level which increase the batter combustion and economic viability of design due to batter thermal efficiency

REFERENCES

1. Census India, Census of India Report, Ministry of Home Affairs, Government of India, 2011. www.censusindia.gov.in.
2. Puri, C. (1988). Analysis of energy consumption and production pattern in Dhanawas: A survey report. Tata Energy Research Institute, New Delhi. Paper No 2/88.
3. Reddy, A. K. N., & Reddy, B. S. (1983). Energy in a stratified society: case study of firewood in Bangalore. Economic and Political Weekly, 18(41), 1757- 1770.
4. J. Goldenberg, T. B. Johansson, A. K. N. Reddy and R.H. Williams, Energy for a Sustainable World, Wiley Eastern, New Delhi, 1988.
5. Pantangi, V. K., Karuna Kumar, A. S. S. R., Mishra, S. C., & Sahoo, N. (2007).Performance analysis of domestic LPG cooking stoves with porous media. International Energy Journal, 8(2). 139-44.
6. Dongbin, Z., Jinsheng, L., Guangchuan, L., Yan, D., Gang, X., & Lihua, L. (2007). Effects on combustion of liquefied petroleum gas of porous ceramic doped with rare earth elements. Journal of Rare Earths, 25, 212-215.
7. Akbari, M. H., Riahi, P., & Roohi, R. (2009). Lean flammability limits for stable performance with a porous burner. Applied Energy, 86(12), 2635-2643.
8. Mujeebu, M. A., Abdullah, M. Z., & Mohamad, A. A. (2011). Development of energy efficient porous medium burners on surface and submerged combustion modes. Energy, 36(8), 5132-5139.
9. Pantangi, V. K., Mishra, S. C., Muthukumar, P., & Reddy, R. (2011). Studies on porous radiant burners for LPG (liquefied petroleum gas) cooking applications. Energy, 36(10), 6074-6080.
10. Indian traditional cookstoves, source: www.gettyimages.com (4/23/2016,14:30)
11. Report of World Health Organization (WHO): "Household air pollution andhealth", source:http://www.who.int/mediacentre/factsheets/fs292/en/5/31/2015. (4/23/2016,14:35)
12. Sunshine Kitchen Appliances, source: www.sunshinesuperkitchen.com. (4/23/2016,14:31) cooking, source: www.tandooriflamesmelbourne.com.au. (4/23/2016,14:32)