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EXPERIMENTAL INVESTIGATION OF PERFORMANCE OF CONVENTIONAL LPG COOKING STOVE

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Abstract

The paper works on investigation of the performance analysis of Conventional LPG cooking stove. The performance parameters are obtained by experimental method. To investigate the areas for improving performance based on the results by proper efficient burner design, produce less pollutant formation and saving losses etc. The performance of the cooking stove was studied using experimental method. The experimental method was carried out using water boiling test and emission test according to IS 4246:2002.

The thermal efficiency was found nearer 66.27 % and the rate of heat generated by burner is 1.7849 KW. In the emission test, the % of volume of CO_2 was found to be 0.9 and the ppm of CO was found to be 50.

1. Introduction

Energy importance in our daily lives derives simply from the fact that it provides essential human services, such as lighting, cooking, motive power, space heating and cooling, water pumping and so on. Liquefied petroleum gas (LPG) is one of the

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commonly used conventional fuels for domestic applications. The fuel of LPG finds very wide application in a large variety of domestic, industrial, commercial and leisure uses. A LPG cooking stove reported by Central Petroleum Research Association, India, In view of huge consumption of LPG in India, there is a need to look at different modifications for improving performance of the stove.

Normally a burner plays an important role in any combustion system. Since proper efficient modifications of a burner often leads to an efficient combustion and possibility to produce less pollutant formation. Its consumption in domestic cooking is increasing every year at the rate of approximately 10% [1]. The total domestic consumption of LPG in India is almost comparable with other petroleum products used in industrial applications [1]. The Overall efficiency of stove depends upon different conditions such as temperature, pressure, wind speed, specific heat capacity of the vessel, overall shape of vessel, weight of vessel, and size of vessel.

First, the conventional burner phenomenon technology is discussed and the experiments of calculating thermal efficiency and measuring emissions are carried out.

2. Conventional Domestic Burner Technology

Normally all types of burners in cooking stoves works on the principle of a Bunsen burner. The schematic typical burner of a conventional LPG cooking stove is shown in Figure 1. It consists of a fixed orifice for gas inlet, two ports for primary air supply, a pipe-shaped mixing tube and a burner head with holes drilled in it fitted on top of the mixing chamber. The narrow zone of the mixing tube is called the throat, which diverges into the hind part is called bell. The gas flow rate is controlled by a valve in the gas line. Positions of the two primary air ports relative to gas inlet port vary according to manufacturers. In some burners, they are located slightly downstream of the gas inlet port.

The high velocity gas jet creates a low static pressure in the burner bell and this causes suction of primary air through the two primary air ports. Air and gas mixes in the mixing tube and through mixing chamber it comes out in the form of jets through the ports of the burner head. The ports are closely located circumferentially and thus the jet flames from the individual ports merge to form a single flame. The secondary air is entrained to the combustion zone from the bottom of the mixing chamber and air also diffuses to combustion zone from the circumferential area surrounding the flame. Thus combustion in the burner of a domestic LPG cooking stove is a partially premixed one. The layout of simulation of flame of conventional domestic burner LPG cooking stove is given in Figure 2.

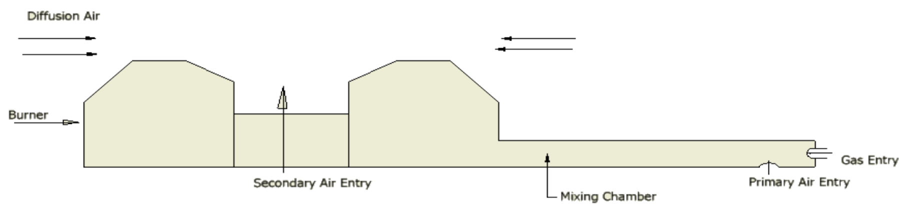

Figure 1. Schematic diagram of a typical conventional LPG cooking stove burner.

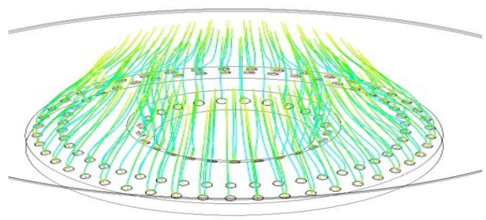

Figure 2. Simulation of flame conventional domestic burner LPG cooking stove using CFX.

3. Experimental Procedure

1. Thermal efficiency test

In India, Bureau of Indian Standards sets guideline for the testing the thermal efficiencies for all types of cooking stoves. For LPG cooking stoves, the thermal efficiencies are determined according to Indian Standard (IS) 4246:2002. The following the guidelines of IS 4246:2002, thermal efficiencies of cooking stoves in the present work were estimated by conducting the water boiling test as per the procedure given in IS 4246:2002.

The test shall be carried out by weighing the gas used. The gas shall be taken from a small bottle containing LPG weighing 2 kg. The bottle shall be fitted with an 'On/Off' valve and shall be connected to a regulator which, in turn, shall be connected to a pressure gauge and to the appliance. A second 'On/Off' gas valve shall be inserted in the gas ways upstream of the regulator as near as possible to the gas bottle. A typical layout of set-up necessary for this test is shown in Figure 3. The photographic views of experimental set up are shown in Plates 1 to 4.

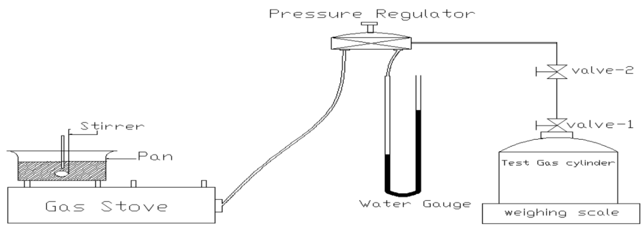

Figure 3. Experiment test set-up for thermal efficiency by weight.

Plate 1. Experimental set up for measurement of efficiency.

Plate 2. Set up for measurement of gas consumption.

Plate 3. Set up for measurement of temperature (RTD).

Plate 4. U-Tube water manometer and variable pressure regulator.

The gas shall be passed at $2492\,KN/m^2$ $(30\,gm/cm^2)$ inlet pressure through the stove for a few minutes to purge the system of air and to establish the gas pressure required. Only one burner of the appliance shall be tested at a time and during the test all gas delivered to the stove shall flow through the jet of the burner being tested. The pan shall be selected and loaded in accordance with the requirements and placed centrally over the burner being tested. The Pt-100 (RTD) temperature sensor is used for measuring accurate temperature parameter. The temperature of the water T_1 contained shall be noted and recorded as long as it remains constant. The bottle shall be disconnected, weighed. Reconnected and valves (1) and (2) opened. The gas control tap shall then be opened and the gas shall be ignited. The water shall be allowed to warm up to about $80°C$ when stirring is commenced and continued until the end of the test. The burner shall be put off when the temperature of water reaches $90°C + 1°C$. The stirring shall be continued and the maximum temperature T_2 shall be noted.

Next, the valves on the bottle and the gas line shall be closed and the bottle shall be disconnected and reweighed. The weighing scale is used which accuracy is $0.1\,\text{gm}$. It is thus possible to estimate the mass of gas used during the period taken for the water to heat up. Thermal efficiency shall be calculated by the following formula:

$$E = \frac{100(G + W)(T_2 - T_1)}{MK},$$

where

$E =$ thermal efficiency of the burner in percent,

$G =$ quantity of water in the vessel in kg,

$W =$ water equivalent of the vessel complete with stirrer and lid,

$T_2 =$ final temperature of water in $°C$,

$T_1 =$ initial temperature of water in $°C$,

$M =$ gas consumption in Kg,

$K =$ Calorific Value of the gas in Kcal/Kg.

The same procedure carried out on conventional burner as given in IS.

2. Exhaust gas analysis test

The appliance was set up in accordance with guideline given in IS: 4246:2002. Before start the experiment, a pan of 170 mm diameter and 75 mm of height and containing sufficient water for the test shall be placed over the burner. In addition a collecting hood was so prepared that not interfering in any way with the normal combustion of the burner. The drawing and picture of fabricated hood for measuring combustible products in Figure 4 and Plate 5, respectively.

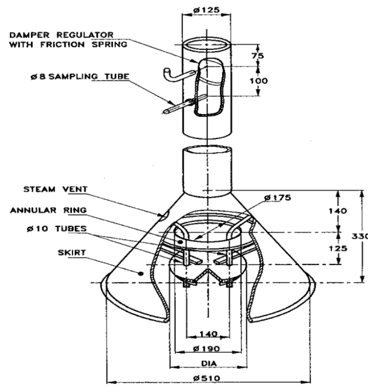

Figure 4. Drawing of hood for burner (Ref. from: IS 4246:2002).

Plate 5. Hood for burner.

The experiment was carried out by the gas analyzer instrument make ACE 9000. The picture of experiment set up for gas analyzer is shown in Plate 6.

Plate 6. Experimental setup for measurement of emissions.

The experiment carried out on condition of when damper is fully opened and fully closed. Based on reading, result was prepared in the tabular form. The Gas analyzer results shown in Table 2 with the hood in position over the burner under investigation, gas admitted at inlet pressure of $2.943\,\text{KN}/\text{m}^2$ and the burner preheated 5 minutes before sampling commenced. The reason for this being that during the first 5 minutes the burner is warming up and proportion of CO may be high.

4. Result and Discussion

The salient features of the results are given and discussed below.

Thermal efficiency

The thermal efficiency calculate by performing experiment as per procedure is given IS. The experiment was performed before burner was pre-heated for 5 minutes. After getting the results, the tabulation is prepared. Table 1 summarizes with conventional burner reading. The average thermal efficiency is calculated as 66.27%.

Table 1. Summarize data for thermal efficiency of conventional burner

I.D.	Pan Weight, Gm	Initial Water Quantity, Gm	Final Water Quan., Gm	Initial Temp T1, oC	Final Temp T2, 0C	Max., Temp, Tmax, 0C	Pr. H1 Cm	Pr. H2 Cm	Gas Consu. Initial Gm	Gas Cons. Final Gm	Total Gas Cons. Gm	Time T, Mint:S	Remarks
1	168.3	1000.3	1059.5	32.5	90.1	93.5	65.5	29.5	2908.5	2897.4	11.1	4:43	Avg. efficiency about **66.272** %
2	174.7	1000.3	1068.1	32.5	90.0	93.6	65.4	29.6	2944.4	2931.8	12.6	4:48	
3	178.0	1000.2	1072.7	32.5	90.1	93.5	65.4	29.6	2931.8	2920.1	11.7	4:40	
4	188.6	1000.4	1083.9	32.5	90.1	93.8	65.5	29.5	2956.7	2944.6	12.1	4:43	
5	213.7	1000.2	1106.0	32.5	90.0	93.5	65.5	29.5	2920.1	2908.5	11.6	4:45	
						93.58					11.82	284 (s)	

Exhaust gas analysis

The emission results are important for environmental impact. In the emission result, the % volume of CO_2 was found to 0.9 and the ppm of CO was to 50.

Table 2. Emission result when damper is fully closed and opened

At morning = 8.25am		
Conventional burner	Fully closed	Fully opened
Parameters		
Tg -°C	88	89
Ta -°C	32	31
CO_2	0.9	0.7
Efficiency	63.9	55.1
EA	649	695
O_2 -%	19.6	19.9
CO-ppm	50	18

One additional test was carried out with stack monitoring (Combustion Analyzer) kit (IMR-2800P) for measuring NO_x and Hydrocarbon. In Table 3 is shown the values of NO_x and HC during four opening conditions of damper, i.e., 100% (fully opened), 75%, 50% and 0% (fully Closed).

Table 3. Emission test result of conventional burner

Conventional Burner	Opening Condition			
	100%	60%	30%	0%
HC	447	957	449	191
NO_x	0	4	7	10

The NO_x is high in mostly 60%, 30% and 0% opening and the HC is also mostly high in all conditions in conventional burner.

5. Conclusion

The experiments were performed as per the procedure is given in IS 4246:2002. To calculate thermal efficiency, experiment was carried out with five pans near same weight for minimizing the error and to prepare the hood for proper measuring emission products.

1. The thermal maximum efficiency of conventional burner was calculated to be 66.27%.

2. The heat released by the fuel for conventional burner is found to be 1.9 kW. In the emission test for conventional burner, when damper is fully closed, the % volume of CO_2 was found to be 0.9, the ppm of CO was found to be 50 and when damper is

fully opened, the % volume of CO_2 was found to be 0.7 and the ppm of CO was found to be 18.

3. The NO_x and HC are high in conventional burner. The NO_x is high in mostly 60%, 30% and 0% opening. Also the HC was mostly high in all conditions in conventional burner.

The present work has shown the possibility of saving energy by doing more work on areas like that provides good insulated materials for conservation of heat below nearer to pan, to optimize fuel combustion rate means maintaining air fuel ratio and to minimize heat losses.

References

[1] Datanet India Private Limited, 2007, Petroleum products, Retrieved March 2003 from http://www.indiastat.com/india/ShowData.asp?secid =18072&ptid=25&level=2 /.

[2] T. V. Ramachandra, D. K. Subramanian, N. V. Joshi, S. V. Gunaga and R. B. Harikantra, End use efficiencies in the domestic sector of Uttara Kannada District, Feb. 1999.

[3] Rahima Akter Lucky and Ijaz Hossain, Efficiency study of Bangladeshi cook stoves with an emphasis on gas cook stoves, Energy 26(3) (2001), 221-237.

[4] Yung-Chang Ko and Ta-Hui Lin, Emissions and efficiency of a domestic gas stove burning natural gases with various compositions, Energy Conversion and Management 44(19) (2003), 3001-3014.

[5] IS 4246:2002 Indian Standard Domestic Gas Stove for Use With Liquefied Petroleum Gases-Specification (Fifth Revision).

[6] Oleg Dzioubinski and Ralph Chipman, Trends in consumption and production, household energy consumption, DESA Discussion paper no. 6.

[7] G. Cook, M. S. Burnett, C. J. Delaney, J. W. Milon, F. T. Plowman, K. Walker and K. E. Wood, Chapter II, Residential Energy Use 1, University of Florida, Energy Information Document 1028.

[8] P. J. D. Lloyd, G. Heinrich and F. N. Mulaudzi, A Comparison of the thermal efficiency of different stoves used nationally in township homes, Domestic Use of Energy Conference 2004.

[9] Weihong Yang and Wlodzimierz Blasiak, Numerical simulation of properties of a LPG flame with high-temperature air, International Journal of Thermal Sciences 44 (2005) 973-985.

[10] Usa Makmool, Sumrerng Jugjai, Suvit Tia, Pumyos Vallikul and Bundit Fungtammasan, Application of particle image velocimetry to analyse thermal performance of LPG cooking burners, As. J. Energy Env. 08(04) (2007), 635-644.

[11] P. Muthukumar, Piyush Anand and Prateek Sachdeva, Performance analysis of porous radiant burners used in LPG cooking stove, International Journal of Energy and Environment 2(2) (2011), 367-374.

[12] V. K. Pantangi, A. S. S. R. Karuna Kumar, Subhash C. Mishra and Niranjan Sahoo, Performance analysis of domestic LPG cooking stoves with porous media, International Energy Journal 8 (2007), 139-144.