Study of effects of various parameter on thermal efficiency of porous burner with kerosene pressure stove

Gyan Sagar Sinha
Kalinga Institute of Industrial Technology, Bhubaneswar

P Muthukumar
Indian Institute of Technology Guwahati, Guwahati

Email: gyan_it002@yahoo.co.in

Abstract. Energy scarcity and pollutants emission are the main concern for world. It is mandatory to develop a device to tackle the energy crisis and pollutants emissions. This paper covers about the thermal demonstration of porous burner with pressure kerosene stove in terms thermal efficiency. This paper also discusses about the effect of vessel diameter and on thermal efficiency. Effects of gap between vessel’s bottoms to burner’s surface on thermal efficiency also have been discussed in this paper. Porous burner with kerosene stove enhance 15 % thermal efficiency as compared to conventional kerosene pressure stove. Maximum thermal efficiency obtained at lower input power. Parametric study have been done in certain operating condition like room temperature, stable combustion, lower power input etc.

1. Introduction

Maximum part of the energy that is used for survive the life comes from the fossil fuel like petrol, diesel kerosene etc. In rural area, cooking is done by biomass (wood, dung cake etc.) which, not only originates the pollutant emission but also endorse the deforestation. Deforestation is bad for our planet. So, now a days, it is necessity to develop a device which does not only reduce the pollutants emission, but also reduces the dependency on reserve of fossil fuel. Due to gradual shifting of economy, people of rural area are using kerosene which provides a clean combustion as compare to biomass. The combustion of LPG is much better than kerosene and biomass, but due to the high cost and poor network, it is not accessible to rural areas people [1]. So people have two choice for cooking, kerosene and biomass. In urban area also, people of low cost income group not able to use LPG because of high cost. So they have only one option to cook i.e. use kerosene. The Government of India is also giving huge subsidy to kerosene so that people can purchase kerosene at low cost. For cooking purpose, kerosene is used in wick stove and pressure kerosene stove. Average thermal efficiency of wick stove (5-10 %) is very low as compared to pressure kerosene stove (45%) [2-3]. Thermal efficiency of Bureau of Indian Standard (BIS) pressure kerosene stove varies between 55-58 % [4]. So kerosene pressure stove is the best choice for cooking for people of rural area as well as in some part of urban area. Thermal emissions (NOx, and
CO) of pressure kerosene stove is very high (CO: 615 – 910 ppm, NOx: 19-35 ppm) [5] as compared to World Health Organization (WHO) guidelines. These high pollutants emissions not only affects the human while they are also creating environment imbalance. So there is a motivation towards develop a device which not only reduce the emissions, but also increase the performance. For better efficient performance of present combustion device, there is a need of alternation of the existing setup. The reason behind of alternation of present combustion device is to make use of energy to upper limit and decrease the pollutants emissions level. Hence, regulatory body and investigator are taking an effort on rising the performance of such device in context to energy conservation and environmental pollution. In kerosene cooking stove with pressure type, combustion takes place in gaseous medium as shown in Figure 1. Burner of kerosene cooking stove with pressure type consists of pair of ascending tube connect with a plane rounding chamber at the top called burner head. A rising tube that attached with the main fuel passage is connected with lower portion of ascending tube. There is a direct connection of bottom of rising tube with pressure tank. A spray nozzle is attached in between the pair of descending tubes. Schematic diagram of kerosene stove burner has been presented in Figure 2. In pressure kerosene cooking stove, combustion takes place on the top of the head of burner and the combustion that happens in the traditional burner is always non lean. Generally, combustion in the burner of pressure kerosene cooking stove takes place in a gaseous environment and the flame occurs stable over the metallic flame ring of the burner as shown in Figure 1.

![Figure 1. Burning conventional cooking kerosene stove [5]](image)

![Figure 2. Schematic of the primus stove burner [6]](image)

Porous media combustion (PMC) is the unique type of combustion in which combustion takes place in solid porous media. Due to solid medium, significant appearance of conduction, radiation and convection modes of heat transfer makes it better for combustion which increase the thermal efficiency and reduce the thermal emissions. Porous burner adds different feature like high flammability limits, higher power density, higher power modulation and low thermal emissions. In porous media combustion, temperature of combustion zone appears low as compared to traditional combustion (free
flame combustion). Due to thick zone of combustion, temperature distribution is almost uniform. Figure 3 shows a schematic diagram of combustion that takes place in porous media.

![Figure 3. Radiation and conduction dominated combustion (PMC) [7]](image)

Due to aforesaid properties of porous media combustion, so far porous burner have been used in domestic as well as industrial purpose. Pottery clay, sodium silicate and saw dust used as porous insert in kerosene stove and results were compared with traditional kerosene stove [8]. For the same stove, further wire mesh roll filled with metal balls, alumina ($\text{Al}_2\text{O}_3$), zirconia ($\text{ZrO}_2$), silicon carbide (SiC), was used as porous insert and examine the performance of stove by Sharma et al. [9]. After the experiment with SiC as porous insert, with optimum fuel flow rate ($130$-$140$ g/hr) and optimum vessel size, Sharma et al. [9] found an improvement in the results as compare to traditional kerosene stove. Again Sharma et al. [10] modified the burner design. They used ceramic heat shield with low thermal conductivity and radiating alumina ball as a porous insert, improvement in thermal efficiency was $15\%$. At the latest, Sharma et al. [11] changed the burner geometry and done exergy analysis. LPG fuel was also combus in porous media. First work was done by Pantangi et al. [12] in IIT Guwahati. They used Silicon carbide and alumina as a porous material and made two layer porous burner. They concluded that diameter of burner and equivalence ratio were important aspect which can affected the thermal efficiency. For optimum equivalence ratio ($0.3$-$0.7$) and burner diameter ($80$ mm), they [12] observed maximum efficiency about $68\%$, which is $3\%$ higher than conventional Burner (CB) Further, Muthukumar et al. [13] used ceramic block instead of $\text{Al}_2\text{O}_3$ ball for preheating zone. They reported peak thermal efficiency approximately $71\%$. Mishra et al. [14] analyzed the thermal performance of LPG with porous inserts with medium scale ($5$-$10$ kW) and done comparison with traditional LPG Stove. They observed improvement in thermal efficiency as compare to traditional burner. Maximum betterment in thermal efficiency was about $9\%$.

For aforesaid burner, there is a requirement of external air supply which is not feasible for domestic purpose. So there is a need of develop Porous radiant burner (PRB) with kerosene stove without supply of external air. From the review [11-14], it was observed that thermal efficiency varies with various parameter. So present paper discusses about the porous radiant burner with pressure kerosene stove without external supply of air and effects of different parameter on thermal efficiency.

2. Experiment Details

2.1 Methodology
For ignition of kerosene stove, a small amount of kerosene is kept in spirit cup and then burnt them through abla\[ze wick. After the attending of steady state as shown in Figure 1, burning wick is quenched. Thermal efficiency of kerosene stove or LPG or PRB stove is measured by water boiling test (WBT). Operating principle of kerosene pressure stove is as following. In this process a fixed amount of water is filled in an optimal size of aluminum vessel at room temperature. After the attending of steady state (according to BIS), vessel along with stirrer and lid are put in burner. In initial, stove weight without vessel is recorded through weighing machine (accuracy ± 1g). Weight of the vessel (with lid and stirrer) along water is recorded individually through weighing balance machine. Mercury thermometer (accuracy ± 0.5 °C) is used to recording Initial temperature \(T_1\) of water. After reaching the temperature (90 ±0.5 °C), vessel is unloaded and then weight of kerosene stove is measured. Difference of initial and final weight stove gives fuel consumed. For maintaining the uniform temperature in the vessel, stirring is done parallel and carry on till the end of the experiment, when the water’s temperature is reached to \((T_2) 90 ±0.5°C\). The time spent to water heating from initial temperature to final temperature (90 °C) is noted. Thermal efficiency is determined by the following formula (as shown in Equation 1). Thermal efficiency is ratio of heat utilized by vessel along with water to heat release by consumed fuel. Thermal efficiency (\(\eta_{th}\)) of the stove is calculated according to Bureau of Indian Standard (BIS) guidelines [4]. The uncertainty of thermal efficiency have been measured through Klein and McClintock method [15] and obtained uncertainty was ±1.40. Pressure range was varied 1.2-1.5 bar for PRB.

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\eta_{th} = \frac{\text{Heat Output}}{\text{Heat Input}} = \frac{(m_w \cdot C_w + m_p \cdot C_p)(T_2 - T_1)}{m_f \cdot CV}
\]

Where \(C_w, m_p, C_p\) and \(m_w\) symbolize the specific heat of water, mass of vessel including lid and stirrer, specific heat of water and mass of water, respectively. \(m_f\) denotes the quantity of the kerosene (kg) used-up and CV is the lower calorific value of kerosene (43890 kJ/kg). \(T_1\) and \(T_2\) are the initial and final temperature of water. For Porous radiant burner with kerosene stove, thermal efficiency has been measure as same as conventional burner. Figure 4 shows the schematic picture of porous radiant burner with kerosene pressure stove.

![Figure 4](image)

### 3 Results and Discussion

Figure 5 shows the thermal efficiency of traditional kerosene stove and porous burner with kerosene stove. The maximum improvement in thermal efficiency is 15 %. Thermal efficiency of Porous radiant
burner varies in the range of (55.5-64.3 %) while for CB, it varies in the range of (48.5-58 %) for the input power range of (3-1.5 kW) [5]. Figure 5 shows that thermal efficiency inversely varies with input power in both CB and PRB. The reason behind of this is following. With increasing input power, heat utilized by vessel along with water is less while loss to surrounding is more resulting less thermal efficiency. Maximum thermal efficiency have been obtained at 1.5 kW input power.

Figure 5. Comparison of thermal efficiency of PRB and CB with different input power [5]

3.1 Effects of vessel diameter on thermal efficiency

Vessel diameter, gap between burner surface and bottoms of vessel and nozzle diameter are the parameters which can affects the thermal efficiency of PRB with kerosene stove. Figure 6 shows the variation of thermal efficiency with the diameter of vessel. With increasing vessel diameter, firstly thermal efficiency increases and then decreases. The reason behind of this was more heat loss (convective and radiative heat) with small diameter vessel resulting lower thermal efficiency and more heat loss to surroundings with big vessel. For above setup, 270 mm vessel diameter was the optimum vessel, which gives maximum thermal efficiency for given condition.

Figure 6. Comparison of thermal efficiency with vessel diameter [5]
3.2 Variation of thermal efficiency with gap between bottoms of vessel and burner’s surface

Figure 7 shows the variation of thermal efficiency w.r.t gap between the bottoms of vessel to surface of porous burner. With increasing gap between the bottoms of vessel to surface of burner leads to decreasing the thermal efficiency. Less gap leads to lower heat loss to surroundings while more gap attributed more loss to surroundings [16].

![Variation of thermal efficiency with gap between bottoms of vessel to surface of burner](image)

Figure 7. Variation of thermal efficiency with gap between bottoms of vessel to surface of burner

4 Conclusions

Porous radiant burner is a promising scope for the people who is living in rural area and some parts of urban area. This burner provide better performance as compared to conventional burner. With increase of input power, due to the rich combustion, more heat loss to surrounding, which lead to decrease in thermal efficiency. Thermal efficiency of PRB depends on the various parameter like vessel diameter, distance between the bottoms of vessel to surface of burner etc. Less gap between the burner’s surface and vessel’s bottom lead to less heat loss to surroundings.

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