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Design and Analysis of Swirl Flow LPG Gas Burner

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Abstract

We did study on Domestic gas burner in which found some researchers performed portfolio analysis on burners. They also perform conjoint analysis in which they assess customers preferences for simulated concepts to improve burner's like and dislike. This study helps in improving or developing gas burner. For analysis purpose we took results of various experiments conducted on domestic burner. Therefore, in this paper swirling flame dynamics are investigated using computational fluid dynamics (CFD) with commercial software (ANSYS). A new generic swirl burner operated under lean-premixed conditions was modelled.

Keywords—*Swirl flow gas burner, Losses, Efficiency, CFD Analysis.*

1.Introduction

Much attention has been paid to higher thermal efficiencies and lower emissions of domestic gas burners since the ever-increasing demand for energy saving and emission reduction. As recognized, the domestic gas burner most extensively used is of the conventional Bunsen type (i.e. Partially aerated). The typical partially aerated burner entrains primary air naturally by a momentum sharing process between the high velocity gas jet and the ambient air. The most popular fuel used in domestic gas burners is liquefied petroleum gas (LPG), which is also used in this work. Typically, designs of conventional domestic gas burners are mainly relied upon open combustion flame such that energy loss through the dispersion of the flue gas to the surroundings is very large, resulting in relatively low thermal efficiency. Clearly, if the dispersion of the flame or flue gas to the surroundings can be prolonged, then the thermal efficiency can be improved. Heat and mass transfer are strongly influenced by swirl in a number of natural and technological flows. However, most of the domestic gas burners are of non-swirl flow type, rather than swirl flow type. Therefore, in order to achieve high efficiency and low emissions, it is of great importance that the swirl flow in a domestic gas burner can be properly designed. Recently, low-emission, energy-efficient gas burners have Attracted much attention. However, there is still lack of studies on the flow type affecting burner performance, especially swirl flow. The objective of this study is to investigate the influence of swirl flow including swirl angle and inclination angle on the burner performance. Domestic gas burners with swirl flow are proposed by adjusting different values of swirl angle and inclination angle. Their thermal efficiencies and CO emissions characteristics will be discussed and compared with those of the convectional non swirl flow burner.

2.Overview of gas burners

The conventional LPG domestic stove was tested for its thermal efficiency and was found as low as 51% under adverse conditions as against 64% specified as minimum thermal efficiency by the BIS. This difference in efficiency has generated an instinct to develop some means or to develop a new burner plate for LPG domestic stove. Authors tried to find out the various thermal losses occurring in the stove and found that they are mainly a) Related to combustion and its products and b) Related to heat transfer. These were analyzed and it was found that swirling flames, porous inserts and low thermal inertia pan support can increase the thermal efficiency of the domestic LPG stove. Among these the swirling flame

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burner cap and pan support is very suitable modification in
the conventional stove. So this were designed and experiments were carried out.

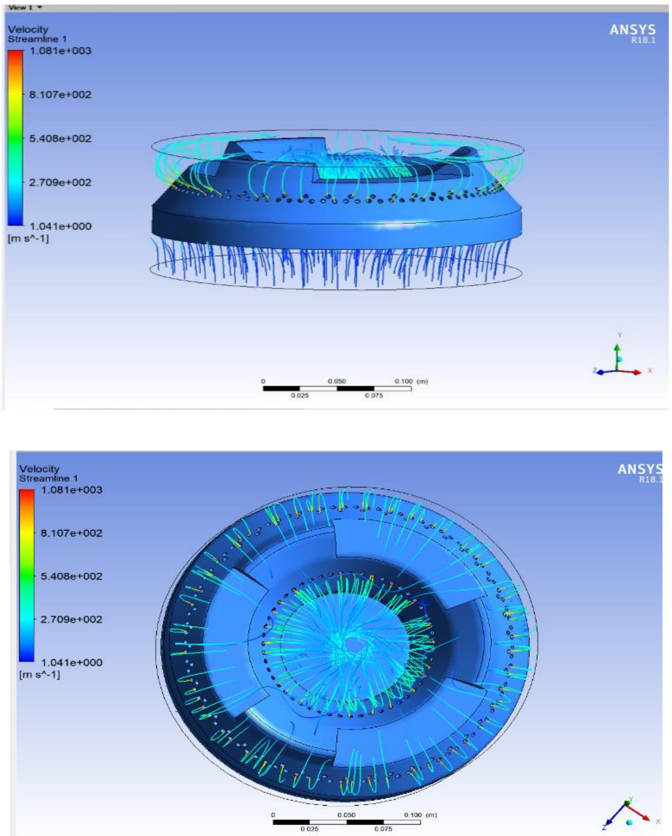

Fig. 1 CFD analysis of domestic gas burner: (a) flow pattern front view and (b) top view of gas flow pattern.

3.Swirl flow gas burner

Domestic gas combustion burners are essential in all cooking household appliances including professional kitchens and restaurants. Developing the burners to be more efficient and safe for the domestic use in a task that manufacturing companies in the industry are taking as a duty to improve and enhance such vital component and on the strict level as the international standards are releasing more constraining regulations to increase pedestrian safety by reducing the consumed energy of burners and also reducing formation of unburnt elements such as "CO, COx and NOx ". Liquefied Petroleum Gas (LPG) is the most common used gas for the domestic use, since it was abundant from the resources point of view in the last 60 years, while the current shift is towards the NG as many fields are been discovered containing a large reservoir for this matter. For Domestic burners the flame is considered stationary flame, and this type of flame is divided into three classes: Aerated flames, Partially-aerated flames and Non-aerated flames. The domestic burners in market are commonly partially-aerated as the burners are designed to be naturally aspirated. The partially aerated burner's properties have relatively high efficiency and good combustion properties. In order to improve the combustion behaviours of this premixed single ring burner, reducing energy consumption and pollutant emission swirling flow has been used. There are multiple types of burners used in the domestic cooking gas burners. These types

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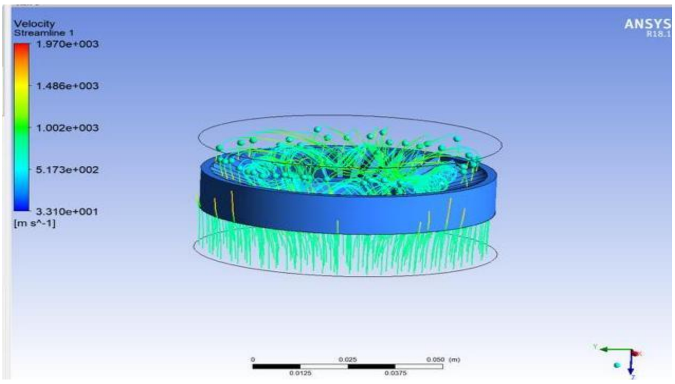
are indicated by: burner sizes, power, number of rings, number of ports, types of ports and angle of impinging. Upon this approach's researches have been done to provide more efficient and reliable appliances, and the focus of this research is on domestic gas operated cooking appliances specifically the hob burners. Swirling flow conducted to the domestic gas burners were studied variously with different designs. All of them concluded that, using swirling flow to enhance the burner thermal efficiency and a swirl flow has a positive effect on the CO emissions. The effect of the mixture Reynolds number and pan height for three single ring burners radial, swirl and star pattern on the thermal efficiency and CO % has been studied using LPG. It was found that swirling flow increase the thermal efficiency in general and slight decrease in emissions. Used natural gas to study the efficiencies and emissions of domestic burners. They found that the thermal efficiencies and the emissions produced from the burner are affected by the thermal input and the load height to flame length ratio. Increasing the pot height to flame length ratio or the thermal input, the burner thermal efficiency increasing. Also, with either thermal input ratio or pot height to flame length, the NOx and NO generally rise. Also, other parameters were studied to evaluate its effect on the performance of the burner, some of these parameters are, the air to fuel ratio or equivalence ratio and swirl number. Flame impinging is a new approach for developing burners with lower CO emissions, and this is achieved by impinging two neighbouring flame fronts together forming one flame front. The aim of this idea is to utilize the momentum of the jets at an angle that introduces a turbulent motion in impinging flame front allowing more air and fuel mixing. This parameter is affected by the flame length and speed as flames tend to attract each other when the flame speeds are higher. In this study all of these parameters are joined together in a comparative form to evaluate which are the effective parameters on improving the performance of domestic gas burner. The study focuses on combining the swirl effects of a single ring burner that operate on a partially premixed mixture flow configuration, with the target of enhancement combustion characteristics by the aid of the swirl effect.



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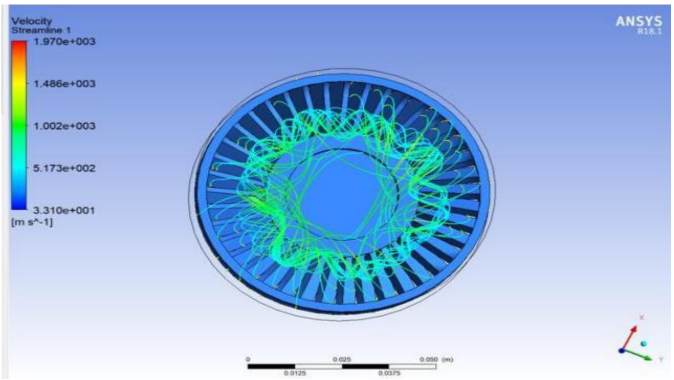

Fig. 2 (a) CFD of Swirl flow gas burner front view and Fig. 2 (b) shows CFD of top view of Swirl flow gas burner.

3.1 Effect of swirl burner's flow on efficiency and cost per cylinder:

a) By increasing the swirl angle the thermal efficiency increases by 2% than conventional burner.
b) Swirl flow burner shows lower CO emission than domestic burner.
c) Swirl flow burner when used with modified pan support increases the thermal efficiency of the stove from 64.22 to 66.59. This slightest rise in efficiency will save approximately Rs. 431.31 crores in domestic sector only. Because of this the operating cost per cylinder will be reduced by Rs.11/-. The cost of the existing burner is approximately Rs.100/- whereas the total cost of proposed burner might be Rs.150/- in mass production. And the cost of pan support will be Rs.50/- Thus the extra cost of the new burner can be recovered within the usage 5 cylinders.

3.2 CO emissions of the swirl flow burner:

The influence of the pan height to the flame front and Reynolds number has been introduced as the changing conditions. To study the improvement of future domestic gas burners by increasing the thermal efficiency as well as decreasing CO emissions, LPG was used as the testing gas for the examination of these burners. The results indicated that, using the swirl motion improved the thermal efficiency and CO emissions, but for the Star pattern burner the CO emissions improved evidently. Increasing the pot height from the burner front flame decreased the thermal efficiency and CO emissions under all operating conditions due to lower pigmentation of the flame to the pan bottom which reduces the heat transfer from the flames to the heated pan. For the Swirl flow burner, the efficiency increased by 2.7% from the benchmarked burner. On the other hand, the CO emission decreased by 80% for the star pattern burner from the benchmark due to two reasons increased first the gaps between each flame length which allowed more air to reach the flames and help complete the combustion process secondly the increased flame length because of impinging flames increased the inertia of the flow which resulted into propagation in the radial dimension decreasing the contact with the heated load. The results showed that the swirl flow burner yields higher thermal efficiency and emits lower CO concentration than those of the conventional radial flow burner. A greater swirl angle results in higher thermal efficiency and CO emission. With increasing loading height, the thermal efficiency increases but the CO emission decreases. For a lower loading height (2 or 3 cm), the highest efficiency occurs at the inclination angle

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15∘. On the other hand, at a higher loading height, 4 cm, thermal efficiency increases with the inclination angle. Moreover, the addition of a shield can achieve a great increase in thermal efficiency, about 4-5%, and a decrease in CO emission for the same burner (Swirl flow).

3.3 Thermal Efficiency calculation:

Three different burners design were tested at different air to fuel ratio (A/F), pan height and burner power to indicate their effect on the burner performance and to find the most suitable and optimum condition for each burner design.

In order to find the thermal efficiency, the International Standard EN 30 [24, 25] test and calculated from the following equations:

$\boldsymbol{EEgasburner} = \boldsymbol{Etheoric} / \boldsymbol{Egasburner}$ (1)

$\boldsymbol{Etheor} = \mathbf{4.186} \times \mathbf{10} - \mathbf{3} \times \boldsymbol{me} \times \boldsymbol{t2} - \boldsymbol{t1}$ (2)

$\boldsymbol{Egasburner} = \boldsymbol{Vc} \times \boldsymbol{Hs}$ (3)

$\boldsymbol{me} = \boldsymbol{me1} + \mathbf{0.213}\boldsymbol{me2}$ (4)

$\boldsymbol{Vc} = \boldsymbol{Vmes} \times \boldsymbol{pa} + \boldsymbol{p} - \boldsymbol{pw}\ \mathbf{1013.25} \times \mathbf{288.15}\ \mathbf{273.15} + \boldsymbol{tg}$ (5)

Where;

- E gas burner: energy content of the consumed gas for the prescribed heating in MJ and rounded to the first decimal place;
- Etheoric: theoretic minimum required energy for the corresponding prescribed heating in MJ and rounded to the first decimal place.
- me: is the equivalent mass of the pan filled
- me1: is the mass of the water used in the pan
- me2: is the mass of the aluminium corresponding to the pan and its lid (the mass me2 to be taken into account will be the mass measured).
- Vc: is the volume of the dry gas consumed, in cubic meters, determined from the measured volume, by the following formula:
- Vmes: is the measured gas volume, in cubic meter
- pa: is the atmospheric pressure, in mbars
- p: is the gas supply pressure at the point where the heart input is measured, in mbars;
- pw: is the partial vapor pressure, in mbars;
- tg: is the gas temperature at the point where the heat input is measured, in degrees Celsius;
- Hs: is the gross calorific value of the gas.

3.3 CO emission’s calculation’s:

On the other hand, to measure the combustion emissions the international standard EN-30European Standard [24, 25] is used. In this standard the combustion emission is evaluated by measuring the CO concentration in the air and water vapor free products (neutral combustion) as shown in the following equation:

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$(CO)\,N = (CO)\,M \times (CO2)\,N/\,(CO2)\,M$

- (CO)N: is the volumetric percentage of carbon monoxide content relative to the dry, air free products of combustion;
- (CO2) N: is the volumetric percentage of carbon dioxide calculated for the dry, air-free products of combustion;
- (CO)M:is the volumetric percentages of carbon monoxide
- (CO2) M:is the volumetric percentages of carbon dioxide measured in the dry sample during the combustion test.

So finally to have as a compromise for an enhanced efficiency and lowered combustion emissions the Swirl burner would be promising to study more, and more cases must be designed for the pattern burner adding an inclination angle to enhance the contact between the flames and the heated load.

4 Conclusion:

1. Swirl burner when used with modified pan support increases the thermal efficiency of the stove from 64.22 to 66.59. This slightest rise in efficiency will save approximately Rs. 431.31 crores in domestic sector only. Because of this the operating cost per cylinder will be reduced by Rs.11/-.
2. The cost of the existing burner is approximately Rs.100/- whereas the total cost of proposed burner might be Rs.150/- in mass production. And the cost of pan support will be Rs.50/- Thus the extra cost of the new burner can be recovered within the usage 5 cylinders. This proposed change can be easily adopted on existing stove.
3. Experimental set up can be developed for a different combination of port angles and their optimum value can be found out. Further efficiency can be enhanced by developing a recuperator, which utilizes a waste heat of the flue gases to preheat the air (reactants), required for the combustion. Also a porous media burner can be developed in which the combustion flame is embedded.

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