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Case study for co and counter swirling domestic burners

Ashraf Kotb*, Hany Saad

Department of Mechanical Power Engineering, Faculty Engineering Ain Shams University, Cairo, Egypt

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ABSTRACT

In this case study, the influence of equivalence ratio for co and counter-swirl domestic burners compared with non-swirl design on the thermal efficiency as well as CO emissions has been studied using liquefied petroleum gas (LPG). Also, the flame stability, and pot height, which is defined as the burner-to-pot distance (H), of the co and counter domestic burners were compared. The analysis of the results showed that, for both swirl burners co and counter one the thermal efficiency under all operation conditions tested is higher than the non-swirled burner (base burner). For example, the thermal efficiency increased by 8.8%, and 5.8% than base burner for co and counter swirl, respectively at Reynolds number equal 2000 and equivalence ratio 1. The co and counter swirl burners show lower CO emission than the base burner. The co swirl burner has wider operation range than counter swirl. With the increase of pot height, the thermal efficiency of all burners decreases because the flame and combustion gases are cooled due to mixing with ambient air. As a result, the heat transfer is decreased due to atmospheric loss, which decrease the thermal efficiency.

1. Introduction

Because its high thermal efficiency and combustion products are relatively clean domestic burners are extensively used all over the world in domestic heating appliances which using Liquefied petroleum gas (LPG). Due to the increasing concerns of society for the environmental protections especially for the indoor air pollution, lower pollutant emissions domestic burners are very attractive [1–5].

Therefore, more studies on domestic gas-fired burners have been carried out to obtain higher thermal efficiencies as well as energy saving and reducing emissions [6–13]. For many cooker-top burners being used recently, slight improvements in the burner thermal characteristics and reductions of pollutants emissions which resulting from a better design will have a significant impacts on energy saving and environmental degradation all over the world.

Junus et al. [10] studied the effects of the domestic burner design factors on pollutant emissions from cooktop burners using natural gas. These factors include cap shape, cap material, cap mass, cap dimension, location on cooktop, grate height, ports spacing and ports shape. As a result of their study they found that with slit ports, without flame insert and without central secondary aeration lower emission rates were obtained. Furthermore, as decreasing the output port perimeter to the area ratio the exhaust emission rate will reduce.

Later, Stubington et al. [11] studied the efficiencies and emissions from domestic burners using natural gas. They found that the load height to flame length ratio and the thermal input effecting on the thermal efficiencies and the emissions produced from the burner. As the pot height to flame length ratio or the thermal input increased, generally reduced the thermal efficiency and the rate of emission for each of the species affected differently. For both NOx and NO generally rise with either thermal input ratio or pot height

* Corresponding author.
E-mail addresses: Ashraf_Ibrahim@eng.asu.edu.eg (A. Kotb), Hany.elsayed@eng.asu.edu.eg (H. Saad).

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Nomenclatures

d	the output burner port hydraulic diameter, mm	Re	Reynolds number of air mixture flow
H	the spacing between the pot and the burner (burner-to-pot distance), mm	Φ	equivalence ratio of the air/fuel mixture
H/d	the pot height to hydraulic diameter ratio	LHV	low heating value, MJ/m^3
		m_w	water mass in Kg
		m_f	the LPG fuel consumption in m^3
		ΔT_w	the water temperature difference, ˚C

to flame length.

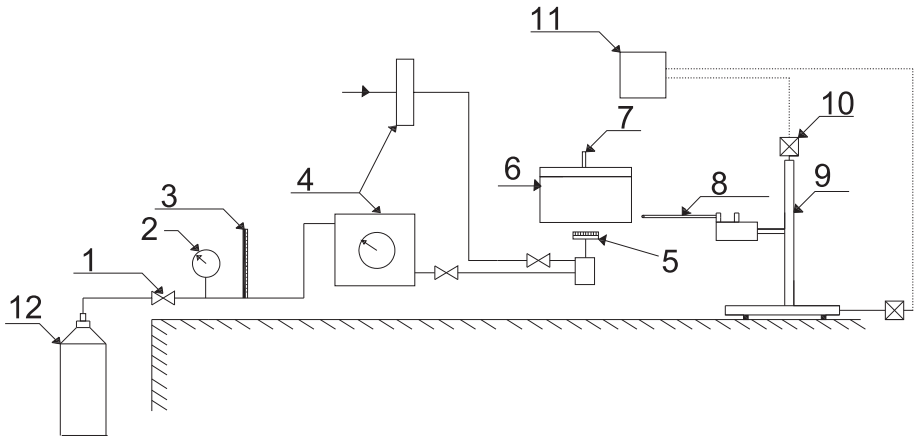
From many years, ago attention paid to the design, fuel and operation factors that affecting the emissions of gas burners and thermal efficiency [13–18]. For example, Ko and Lin [15] studied the effects of the variation of the gas composition on the burner performance and operation. They proposed a suitable design for the domestic stoves using natural gas as a fuel with various heating values. They concluded that using the higher heating value natural gas instead of the lower heating value one results in an increase in thermal efficiency as a result of the higher thermal input as well as an increase in CO gas emission due to incomplete combustion. Also, Huang et al. [16] investigated the thermal characteristics of impinging circular laminar premixed flame with induced swirl. It is observed that with the impingement plate a more uniform heat flux received. Also, Luo et al. [17] found that, in the premixed flame strengthens of a swirling flow the entrainment of ambient air induces a larger contact area. Hou [18] concluded that the burner ports configurations have a considerable effects on the burner emissions and the combustion efficiency.

On the other hand, LPG or natural gas is commonly used as a fuel in domestic gas appliances. Also, most of conventional domestic burner designs have typically depending on open combustion flame, which means a large amount of energy will loss through the combustion process. This means that the thermal efficiency of the burner will be relatively small [22]. For this reason, if the flue gas or the flame dispersion to the surround can be delayed, then the thermal efficiency can be improvement. Shtern et al. [23] concluded that using swirling jets significantly influences the heat and mass. However, most of domestic gas burners using no swirling ports. Although swirling flow field have a great potential to extend the residence time which increase and enhance the flow mixing by using the flow rotational motion [17–21].

Zhen et. al. [24] concluded that the swirling flow has been successfully induced in many industrial applications with small-scale. They designed two swirl domestic burners I and II with different swirling motion methods. They compared these two burners with a Benchmarking cooker. They found that both designs give higher heating efficiency under most operation conditions tested. Domestic swirl Burner II shows lower CO emission than the swirl burner I. They also indicate that using swirling flow in domestic burners is possible to improve the thermal efficiency. However, the swirl generation techniques are very important as the thermal and emission characteristics affected, but less investigations in this field were carried out.

Therefore, this paper presented an investigation for a comparison between the characteristics of two designs, co and counter swirling domestic burner. The influence of the gas flow rate on the thermal efficiency and CO emissions are investigated.

The experimental results obtained from comparing the thermal and emission characteristics of a swirling co and counter domestic burner in this work will help to understand the effect of the swirling direction on the thermal efficiency and emission pollution.



1	Regulating valve	3	Fuel Thermcouple	5	Burner head	7	Thermometer	9	2-D Positioner	11	Computer
2	Pressure gage	4	Flow Meter	6	Loading Vessel	8	Thermocouple S-type	10	Stopper motors	12	LPG Steel Cylinder

Fig. 1. Schematic diagram for the test rig.