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Development of a High Efficiency Burner for Large Scale Cooking for Application in Developing Economies

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Abstract

Star Burners named because of its shape and are widely used in the hospitality industries of Bangladesh such as hotels, restaurants, youth hostels, military barracks, and community centers. The Star Burners though popular are not energy efficient and was not purpose designed for cooking. The Star Burner was developed in the United States of America in the early nineteen hundreds for garbage incineration. Star burners gained popularity in Bangladesh for high volume cooking because of its simplicity of its design and ease of its construction. But in this energy efficient era it is high time that the Star Burner design was modified to make it more energy efficient preserving fuel. Developed countries have switched to ovens for mass cooking which although energy efficient is costly in the context of Bangladesh. In this paper we are reporting on a high energy efficiency burner named the *Dream Burner* we have developed as a more energy efficient replacement of existing star burner for mass cooking with the intended application in Bangladesh and other developing countries. Our purpose designed burner is more energy efficient, constructed using indigenous knowhow using recycled materials, and costs the same as the inefficient star Burner. The modified burner is a four ring concentric burner purpose made for mass cooking with perforations and swirls with optimized throwing angle with individual control knobs to control gas flow. A special feature of our burner is that it is a duel fuel burner that does not require specialized nozzles to switch from natural gas application to liquefied petroleum gas application. In a controlled experimental program comparing the performance of the existing Star burner to our Energy Efficient Burner, the performance of the newly designed dream burner showed that the modified burner reduced the amount of natural consumed by 50% and when using liquefied petroleum gas as fuel our modified burner was 33.5% more efficient than the star burner. The dream burner has been evaluated by utility companies in Bangladesh and international patent has been filed so that in the very near future it will be available commercially.

Key words: Burner, high volume cooking, energy efficient.

1. Introduction

An energy inefficient star shaped Burners commonly called the Star Burner in Bangladesh is used for high volume cooking (cooking meals for more than fifty people). Star Burners are widely used in the hospitality industry of Bangladesh such as restaurants, hostels, community centers; where cooking in mass is an everyday affair. The Star Burners although popular are not energy efficient and was not purpose designed for mass cooking. The Star Burner (refer to Picture 1) wasdeveloped in USA in the early nineteen hundreds for garbage incineration and has since been phased out in developed countries [1,2,3]. The popularity of these burners in Bangladesh is simply because of ease of construction not taking into account any concepts of thermal efficiency in its design. The existing energy inefficient Star burner due to its ineffective design restricts the actual area that is directly heated by the flame. The area of coverage by direct heating is only thirty three percent [2]. Furthermore the burner has no control to optimize fuel to air mixture resulting in incomplete combustion, The design of the burner dose not optimize for flame throwing angle or even have in place a casing to reduce convective heat-loss. There is no set optimized loading high for the cooking utensils. The inherent gaps in the design of the Star Burner have the end result of an energy inefficient fuel guzzling burner [1,2]. In the era of energy efficiency to mitigate global warming it is high time that the Star Burner is phased out to make way for a more energy efficient burner that will not only reduce the cost of cooking but also preserve our precious source of clean fuel such as natural gas (NG) and liquefied petroleum gas (LPG). In this paper we are reporting on a modified high energy efficiency burner termed *The Dream Burner*(refer to Picture 2) that has recently purpose developed as a more energy efficient replacement for the existing star burner. The Dream Burner is purpose designed for mass cooking application in Bangladesh. Our purpose designed burner is energy efficient, and constructed using recycled metal andbased on indigenous technical knowhow.

Figure 1. The existing Star Burner in use showing the inefficient operation due to inherent design flaws leading to low thermal efficiency and high consumption of fuel.

Figure 2. The purpose designed energy efficient burner developed in this study showing clean burning with effective coverage with optimum flame throwing angle leading to high thermal efficiency and low consumption of fuel.

2. Problem identification and basic principle

The purpose designed duel Fuel (natural gas and liquefied petroleum gas) High Efficiency Burner-named the "Dream Burner" is a four ring concentric burner purpose designed for mass cooking. The modified burner has perforations and swirls at optimized throwing angle to ensure efficient burning, further individual control knobs is used to control gas flow in each concentric ring further ensuring energy efficient burning with the area of coverage by direct heating over ninety percent[2,4-8]. The Dream burner is also optimized for inclination angle of the flame, loading height, and gas flow rate. A special feature of our burner is that it is a duel fuel burner that does not require specialized nozzles to switch from natural gas application to liquefied petroleum gas application. The modified burner is casted out of recycled iron using readily available and practiced knowhow already established in local small foundries found in Bangladesh. This performance of the purpose designed burnerfor mass cooking was evaluated in terms of thermal efficiency and fuel consumption against the inefficient Star burner currently mass applied in Bangladesh in controlled laboratory thermal evaluation experiments.

3. Methodology

The experimental program involved construction of numerous burners taking into account features for optimizing maximum efficient burning. The burners were constructed using recycled melted steel and casted in the traditional mode of sand casting in local small foundry. The casted burners featuring different design modifications were optimized by trial and error by comparing modifications done with evaluation of thermal efficiency and fuel consumption, thereby producing an optimum design. The overall comparative control in the experimental program was the existing Star Burner against which our improved designed Dream Burner was compared to with respect to fuel consumption and thermal efficiency.

For evaluating of thermal efficiency and fuel consumption 30 kg of water was heated to 80 ^{o}C in utensil pot and the amount of consumed fuel (natural gas or liquefied petroleum gas) consumed was measured. The loss of water due to evaporation was also measured. Volume of natural gas consumed was measured using a Wet Gas Meter and the amount of liquefied petroleum gas consumed was measured gravimetrically. The thermal efficiency for the experimental runs was determined by using Equation (1) below [2,4,5]:

$$ŋ = \{M_w \times S_w \times (T_b - T) + M_v \times S_v \times (T_b - T) + M_{steam} \times L_w\} \div \{M_{fuel} \times K_{fuel}\}$$

ŋ	=	Thermal Efficiency (%)
M_V	=	Mass of vessel (Kg)
S_v	=	Specific heat capacity of vessel (J/Kg ^{o}C)
(Ta – Tb)	=	Change in temperature from initial to 80^{o}C
S_w	=	Specific heat capacity of Water (J/Kg ^{o}C)
M_w	=	Mass of Water
M_{steam}	=	Mass of water evaporated (Kg)
L_w	=	Latent heat of evaporation of water (J/Kg)
M_{fuel}	=	Mass or volume of fuel consumed (Kg or m^3)
K_{fuel}	=	Calorific value of fuel (J/Kg or J//m^3)

Experimental data or calculated data are reported as Mean ± SEM.

4. Results and discussions

In developing our fuel efficient burner for mass cooking application we started with the same radial dimension as the existing Star burner to ensure that it would be applicable for the needs of cooking using utensils commonly used in Mass cooking in Bangladesh. This calls for a ten inch burner. But herein lays the end of similarity between the existing inefficient Star burner and our purpose designed fuel efficient burner termed the Dream burner. The Star burner is in the shape of a Star and the area of coverage by direct flame heating based on the area covered by each of the six 1.25 inch by 5.0 inch heating platforms (refer to Figure 1). The area of the utensil covered by direct heating is thus limited to thirty three percent of the utensil. In contrast the Dream burner was designed to have concentric rings of fire to ensure more coverage of the utensil by direct flame (refer to Figure 2). The end result was a burner having an area of direct coverage of ninety one percent of the area of the utensil loaded. Figure 3 shows the picture of the Star burner superimposed on top of the newly designed more efficient Dream burner clearly showing the increase in the area of direct coverage by the flames.

Figure 3. The purpose designed energy efficient burner developed in this study with the Star burner superimposed on it showing the effective area increase in direct flame coverage.

By optimizing for thermal efficiency we angled the surface of the concentric ringed Dream burner to through the flame at an angle. The angle of the flame can clearly be seen in Figure 2. The angling ensures coverage of any dead space by overlapping flame from the outer concentric rings. We obtained maximum thermal efficiency when the flame throwing angle was established at 30 degrees .Next we ensured that our burner was enclosed in a casing to prevent heat loss and the optimum loading height of the utensil was established. All this was established by trial and error by changing loading height and optimizing for thermal efficiency. The optimum utensil loading height was experimentally determined to be 3.5 inches. To ensure proper fuel to air mixture we placed nozzles and control knobs for each burner. The end result is a clean burning blue flame as seen in Figure 2. In contrast the convention star shaped burner currently being used in Bangladesh does not have a mechanism to control fuel to air ratio. The end result of all the design features incorporated on the newly developed burner for application in mass cooking in Bangladesh is a far more energy and fuel efficient burner than the current Star shaped burner being used in Bangladesh. Figure 4a and Figure 4b reports on test runs under controlled conditions comparing the thermal efficiencies of the newly designed burner the energy efficient burner to the commonly used Star burner for both natural gas and liquefied petroleum gas respectfully. When using natural gas as fuel the thermal efficiency of the purpose designed Dream burner was experimentally determination to be 60.91 ± 0.13 (n = 3) percent while that of the Star burner was 40.85 ± 0.05 (n = 5) percent. When using liquefied petroleum gas as fuel the thermal efficiency of the purpose designed Dream burner was experimentally determination to be 46.38 ± 0.25 (n = 3) percent while that of the Star burner was 33.10 ± 0.03 (n = 5) percent. The data clearly shows that the design modifications incorporated into the Dream Burner produced a much more thermally efficient burner. In terms of fuel savings this correlates to a reduced the amount of natural consumption of 50% and when using liquefied petroleum gas as fuel a reduced liquefied petroleum gas consumption of 33.5%.

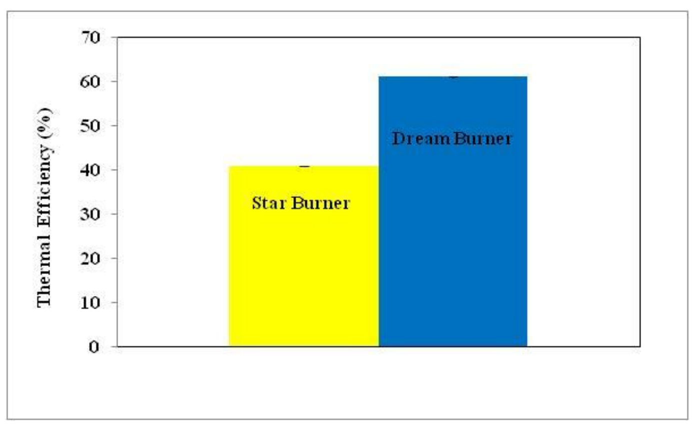

Figure 4a. Bar graph comparing the thermal efficiency of the newly designed burner the energy efficient burner Dream Burner to the commonly used Star burner when using natural gas as fuel.

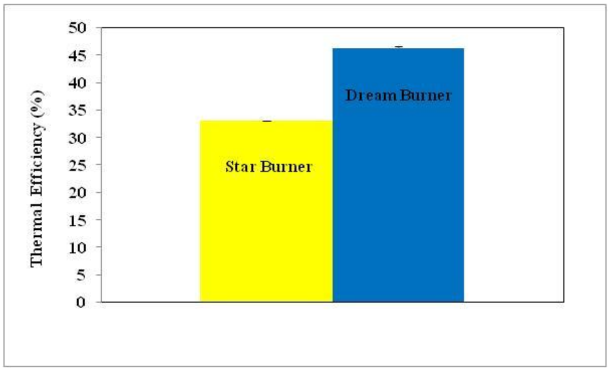

Figure 4b. Bar graph comparing the thermal efficiency of the newly designed burner the energy efficient burner Dream Burner to the commonly used Star burner when using liquefied petroleum gas as fuel.

In simple terms to cook the same amount of food the energy efficient newly developed Dream burner will use fifty percent less natural gas and if one is cooking using liquefied petroleum gas will use thirty percent less liquefied petroleum gas than the existing star burner currently being used in a large scale in Bangladesh. The utilities industry reports that there are 6000 registered connection for mass cooking in Dhaka city, the capital of Bangladesh with a population exceeding fifteen million, and we assume conservatively that each connection is connected to one single Star burner, thus conservatively in Dhaka city alone there are 6000 star burners functioning. If the registered Star burners are replace by our more energy efficient Dream Burner, there is the potential in Dhaka city alone to save 72 million cubic meters of natural gas annually. The Dream Burner is a Bangladeshi Technology purpose built for the people of Bangladesh to help Bangladesh grow in a sustainable greener manner.

5. Conclusions

The purpose designed energy efficiency burner (*The Dream Burner*) that was developed as a more energy efficient alternative to the Star Burner has been evaluated by different utilities and patent has been filed so that in the very near future it will be available to the public. This burner has the potential to drastically impact the mass cooking industry in Bangladesh and possibly other South Asian countries with respect to dramatically reduced consumption of natural gas and liquefied petroleum gas and thus serving as a greener mass cooking option.

Abbreviations

LNG = Liquefied Petroleum Gas
NG = Natural Gas
SEM = Standard Error of the Mean

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Commonwealth Energy and Sustainable Development Network (CESD-Net)

CESD-Net is a major global initiative in energy and sustainable development. The objective of network is to promote energy and sustainable development in commonwealth countries.

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The 1st International Conference on Energy, Environment and Economics (ICEEE 2016) was held at Heriot-Watt University, Edinburgh, EH14 4AS, UK, 16-18 August 2016. ICEEE2016 focused on energy, environment and economics of energy systems and their applications. More than fifty eight delegates from 31 countries with diverse expertise ranging from energy economics, solar thermal, water engineering, automotive, energy, economics and policy, sustainable development, bio fuels, Nano technologies, climate change, life cycle analysis etc. made conference true to its name and completely international. During conference total 51 oral presentations and six posters were shared between delegates. The presentations showed the depth and breadth of research across different research areas ranging from diverse background. ICEEE2016 aimed:

- To identify and share experiences, challenges and technical expertise on how to tackle growing energy use and greenhouse gas emissions and how to promote sustainability and economical, cost effective energy efficiency measures.

In total 11 technical sessions and two invited talks both from academia and industry provided insight into the recent development on the proposed theme of the conference. Preparation, organisation and delivery of the conference started from July 2015 and further co-ordinated by vibrant team of Conference Centre, Heriot Watt University. Conference organisers would like to acknowledge support from the sponsors particularly World Scientific Publication ltd and its team members for the delivery of the conference. Organisers are also thankful to all reviewers who contributed during peer review process and their contributions are well appreciated. At the end and during vote of thanks following awards have been announced and we would like to congratulate all well deserving delegates.

- Best Paper –Academia: Amela Ajanovic, EEG, TU Vienna, Austria
- Best Paper – Student : Christian Jenne,University of Duisburg-Essen, Germany
- Best Poster – Student: Yoann Guinard, University of New South Wales, Sydney, Australia
- Best Poster – Academia: E. Salleh, Universiti Kebangsaan Malaysia, Malaysia
- Active Participation Award - Yoann Guinard, University of New South Wales, Sydney, Australia

At the end we would like to extend our gratitude to all of you for your participation and hopefully welcome you again during ICEEE2017.

Editors:

Dr. Singh is Senior Scientist at Indian Agricultural Research Institute, New Delhi, India. Her area of expertise are bio energy and bio fuels, environmental engineering, carbon accounting and renewable energy integration for rural development.

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