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Research Article

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DESIGN MODIFICATION AND PERFORMANCE TEST OF TWO POT HOLE METALLIC IMPROVED COOKSTOVE

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ABSTRACT

Metallic Improved Cooking Stoves (MICS) are frequently used for cooking and space heating purposes in high altitude. Modification of design to increase its thermal efficiency keeps importance economically, socially and environmentally. Alternative Energy Promotion Center (AEPC) standard 2-pot MICS model has been evaluated and modified with thermal efficiency view point. Several stove configurations has been tested in the laboratory. Rectangular shape of the existing stove has been modified to a suitable curved shape to increase heat transfer and to enable stack effect in stove. Thermal efficiency has been decreased during opening of door of MICS in an average 3%. Thermal efficiency has been increased during modification of MICS by 4%.

Keywords: Cookstove, thermal efficiency, hot start, cold start, simmering.

INTRODUCTION

Most of the rural households in Nepal use fuel wood as the primary source of the energy. The demand of fuel wood is ever increasing while the limited fuel wood resources are causing rapid forest depletion and deforestation. Accessibility to the National electric grid by rural people is very limited, while LPG gas and kerosene oil in the high altitude and remote areas is very costly due to the transportation costs. Therefore, people living in remote areas depend heavily on forest resources to meet their demand for cooking energy. In rural areas which almost account 88%of national population and total of 80 %of the total energy requirements of the country is mainly used for cooking and space heating[WECS, 2010]. Almost all rural energy consumption is from traditional biomass resources, such as fuel wood, agricultural residue sand animal dung. Majority of households in remote areas of the country use open fire places inside their homes for cooking and heating purposes. This adversely affects their health and are primary causes of many respiratory disease especially among women and children(who are frequently exposed to the open fire places than working men). The “pine” and “uttish” woods used in the high altitude regions of Nepal have a lot of resin and they burn producing lots of black harmful smoke [Bhandari*,* 2010].Metallic Improved Cookstove (MICS) is a device that is designed to consume less fuel and save cooking time, convenient in cooking process and creates smokeless environment in the kitchen or reduction in the volume of smoke produced during cooking compared to the traditional stove mud and brick stoves. The MICS have better efficiency, relatively long life, less smoke production and low fuel wood consumption over traditional cooking stoves [Shrestha*et al.,* 2015]. In high altitude areas of the country, fuel wood is needed for both cooking and space heating purposes contrary to Tarai (lower altitude areas) where fuel woods are mainly used for cooking. This results in continuous forest degradation, nutrient depletion from soils (by burning agro waste and cow dung), low agricultural outputs and soil erosion. Together, these aspects result in a further reduction of accessibility to fuel wood [Sharma*et al.,* 2012].In 2009/10 KU launched their KU 2 design stove for high hills and mountains. It is an improved version of the KU-1 model and is incorporated with the water heating systems. Government however provides subsidy to the users of metallic cooking stoves for higher altitudes [Subedi, 2012].Efficient and maximum utilization of MICS contribute to less environmental pollution and sustainable rural development. On has been providing subsidy to deliver it in rural areas. Many poor families cannot afford to pay the cost of MICS without subsidy and instead they stick to the traditional stoves consuming more fuel wood in smoky environment. Initially, Subsidy was provided by government to all types of stove but recently the scheme only provides subsidies buying MICS. The present model of 2-pot MICS is a rectangular cuboids model which has door opening to feed the fuel and dampers to control air draught in the stove. [Sai Bhaskar, 2012]. The front door needs be closed while cooking for funneling out smoke from the kitchen via chimney. The present MICS stoves are less efficient stoves than gasifier and biocharstoves [Gautam*et al.,* 2021].A Metallic cooking stove is composed of various components which are assembled together to function as a single unit. Some of the components are the basic components that all the Metallic Cooking stove must have in order to operate properly. Whereas some components are incorporated in a simple cooking stove in order to increase its performance by reducing the consumption pattern of fuel wood and sustaining a clean environment as well.

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Detail description of existing 2-pot MICS

Stove Top: It is made up of 4mm MS Sheet of dimension 600 mm × 300 mm with all corners being round. It consists of 2 pot hole of 180 mm and 150 mm diameters (rings of different diameters can be fit according to requirement) and 1 chimney hole of 90 mm diameter.
Stove wall: It is made up of 2 mm MS Sheet. It consists of 2 rectangular Sheet of 270 mm × 160 mm and 210 mm x 90mm used for fuel entrance.
Side plates: The 2 side plates are made of 600 × 220 mm dimensions.
Grate: It is made up of 2 mm MS Sheet. Rectangular plate is made of 312 mm × 240 mm. 18 holes of 20mm diameter are made in the plate to allow the ash to fall to the ash tray.
Ash tray: It is made up of Ms Sheet of 2 mm thickness of dimension 270 mm × 36 mm and holes of 16 mm are made at front for air

entrance. It is located just under the grate. This can be pulled out according to requirement.

Inclined Plate: It is made of MS Steel of thickness 2 mm and dimension and needs to be placed at 45 degree angle.

Chimney: It is made up of about 90 mm diameter and 115 mm height and was bending by 45 degree angle and extended up to the surrounding. The thickness is 2 mm. At center of the surface of chimney through holes are made for damper support. Damper: It is a butterfly valve of 65 mm diameter. A 2 mm circular plate of MS Sheet of area about 80% of inner circular area of chimney was attached to a metal rod. Handle was attached to the valve for easy operation. The damper angle was varied and efficiency was checked for our experiment. Baffle: It is a semicircular plate of 55 mm radius and 2 mm thickness. It is attached on base plate of flue passage. Fuel

Door: It was made up of MS Sheet of dimension 260mm × 175 mm and 2 mm thickness. The social acceptability of the MICS stoves are limited due to its fuel conditioning and operational limitations. Most of the people in rural Nepal spend a lot of time and face difficulties to collect fuelwood from forests because of limited availability of fuelwood resources. [Subedi*et al.,* 2012].Furthermore, uneducated social users are not well informed and complexity in design of the present MICS models makes it difficult for the users in operating the damper, door and chimney of the 2-pot MICS stove. Fuel wood needs to be chopped/conditioned to small pieces before using in the present 2-pot models. Fuel conditioning has a very negative social perception and it is regarded as tedious and time consuming job. Most of the users favors open-door cooking over closed-door cooking during the use of the stove [Shrestha*et al.,* 2009].Sole purpose of this study is to modify existing of 2- pot MICS stove to increase overall heat transfer to the stove. This is accomplished by enabling stack effect in the stove due to its curved shape for direct heat transfer to the pots and reduction the heat loss from wall [Ragland *et al.,* 1991]. Several stove configurations were tested using G.I sheets to find out most adequate shape and size of the stove. Modifications tested for the stove in the laboratory were taken by hit and trial method. New model proposes to overcome social and operational limitations of the existing stove by removing the front door. Objective of this paper is to find the effect on thermal efficiency during opening of door and overall thermal efficiency increase with modification of design.

MATERIAL AND METHOD

Existing rectangular shape has been modified to curvilinear shape to make as stream line shape and to reduce heat loss through the wall of the cook stove. Solid works simulation has been done to find the direct heat transfer and temperature distribution to the pots for rectangular and curvilinear shape models has been prepared. Water boiling test has been performed to fine the thermal efficiency of cook stove. The Water Boiling Test (WBT) is a simplified simulation of the cooking process. It is intended to measure how efficiently a stove uses fuel to heat water in a cooking pot and the quantity of emissions produced while cooking. The entire WBT has been conducted at least three times. Water boiling test consists of high power cold start, high power hot start cold start and low power simmering test.

- For cold-start high-power phase, the tester begins with the stove at room temperature and uses fuel from a pre-weighed bundle of fuel to boil a measured quantity of water in a standard pot. The tester then replaces the boiled water with a fresh pot of ambient-temperature water to perform the second phase.
- The hot-start high-power phase is conducted after the first phase while stove is still hot. Again, the tester uses fuel from a pre-weighed bundle of fuel to boil a measured quantity of water in a standard pot. Repeating the test with a hot stove helps to identify differences in performance between a stove when it is cold and when it is hot.
- The simmer phase provides the amount of fuel required to simmer a measured amount of water at just below boiling point for 45 minutes. This step simulates the long cooking of legumes or pulses common throughout much of the world.

By reducing the surface area and narrowing down the top of the stove, overall heat transfer to the stove is increased by Stack effect based on Continuity equation[GACC, 2014].

RESULTS AND DISCUSSION

Modification of existing design

Existing MICS has been shows comparison of surface areas of existing MICS and the proposed MICS with curvilinear shape modifications. Figure 1 and Figure 2.

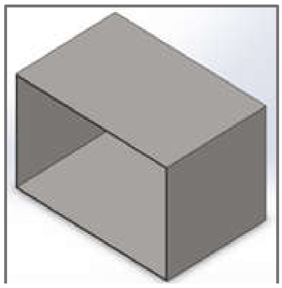

Figure 1: Existing shape

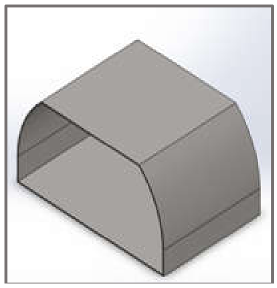

Figure 2: Modified shape

Simulation analysis

For verifying that the modifications increases the direct heat transfer to the pots, rectangular and curvilinear shape models has been prepared and thermal analysis to find out temperature distribution has been done using Solid works simulation.

The simulation details;

Analysis Type	: Thermal
Mesh Type	: Solid mesh
Solution Type	: Steady state
Material	: Plain carbon steel

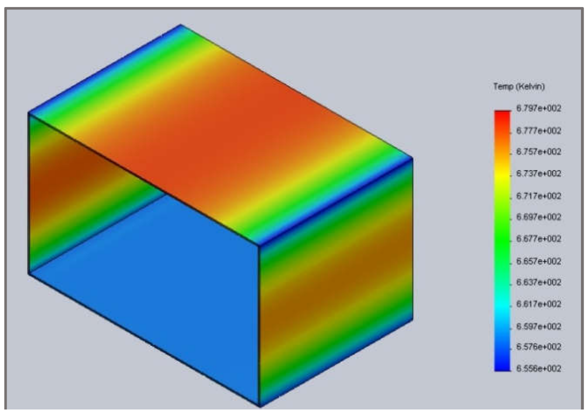

Figure 3: The temperature distribution for the rectangular shape model

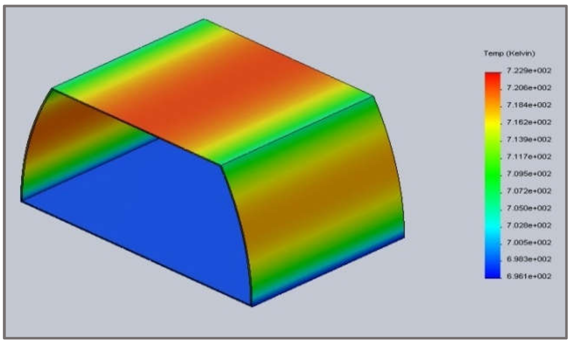

Figure 4: Temperature distribution for curved shape

From above two temperature distribution graphs for the given shape, it was found that heat transfer to the top part of the stove was increased due to Stack effect based on principle of continuity (mass conservation) in the stove. The curvilinear shape had higher temperature at the top surface which shows direct heat transfer to pot increases due to stack effect.

Thermal efficiency test

Thermal efficiency of the cook stove has been obtained by Water Boiling Test of 4.2.3 version[10].One of the social issue is the problem of the door in which small pieces of fuel is required. People use normal size wood and making small pieces is time consuming and need more cost also.

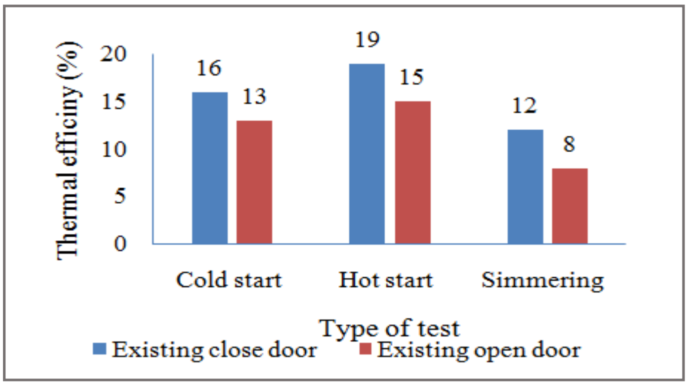

Figure 5: Comparison of thermal efficiency at open and closed door condition

Thermal efficiency of MICS during close and open condition of door shown in

Figure *5*. Thermal efficiency decreases during opening of door at high power cold start and high power hot start by 3% and 4% respectively. During low power simmering test, thermal efficiency has been decreased to 4%. This is due to heat loss from the opening of the cook stove. So, lower power test, feeding rate of cook stove is low and decreases thermal efficiency with high amount. So, for simmering process, door should be closed to get high thermal efficiency. During opening of door, more heat will escape from opening.

Table 1: Comparison of thermal efficiencies (%)

Thermal efficiency test	Close door			Open door		
	Existing	Modified	Net increase	Existing open door	Modified open door	Net increase
Cold start	16	19	3	13	17	4
Hot start	19	22	3	15	19	4
Simmering	12	14	2	8	12	4

Cook stove has been modified by making curve shape which will reduce the surface area and directs heat at the top of the cook stove. With the modification of cook stove by making curve shape thermal efficiency has been increased by an average 3% high power test and2% in low power test during close of door. For open door also, with the modification of cook stove by making curve shape thermal efficiency has been increased by an average 4% high power test and low power test. The WBT tests results shows that by reducing the surface area making curved shape of the 2-pot MICS stove the thermal efficiency is found to be increased.

Conclusions

Following conclusions have been drawn from the study

- Thermal efficiency of cook stove has been decreased during opening of door in hot start, cold start and simmering have been found by 3%, 4% and 4% respectively.
- Thermal efficiency of cook stove has been increased during modification in cold start, hot start, cold start and simmering have been found by 3%, 4% and 2% respectively in closed door condition. Similarly, for open door condition, increase in thermal efficiency has been found by 4%.

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