Design Optimization of Improved Cooking Stove Using Insulating Material

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Abstract

Improved Cooking Stove (ICS) is boon to the developing country like Nepal where more than 80% of the population residing on the rural areas depend on firewood as the main source of fuel to fulfil their daily energy needs. Various government agencies, NGO's, INGO's are working in the field of ICS since years back but, the achievement made is only satisfactory. This research paper focus on technical, economical and social consideration of improved cooking stove and address different process for user friendly fabrication of improved cooking stove with minimum utilization of raw material. Considering normal cooking practice for rural community of Nepal, stove has been design for sitting mode which includes one chimney, two pot holes, two feeding doors, two grate and modified top plate of mild steel. Addition feature include isolite insulating brick which helps to retain heat inside combustion chamber resulting increase in temperature, turbulence and time for higher thermal efficiency, lower specific fuel wood consumption, better fire power and burning rate. This paper describe three different design, whose performance was compared based on Water Boiling Test which follow the calculations based on Shell foundation Water Boiling Test Sheet Version 3, published by Aprovecho Research Centre. The average thermal efficiency based on water boiling test of Prototype #1, #2, #3 and #4 in cold start, hot start and simmering are 14-16-13 %, 18-19-9 %, 13-26-18 % and 23-26-22 % respectively.

Keywords: Improved Cooking Stove (ICS) , Traditional Cooking Stove (TCS), Isolite Insulating Brick, Water Boiling Test, Thermal Efficiency

1. Introduction

Cooking on an open fire is very inefficient. Most of the energy in the wood is lost rather than being transferred to the cooking pot. In many places of the developing world this method is currently in practice.

Improved Cooking Stove(ICS) is a stove that is designed to improve combustion efficiency of biomass, consume less fuel, save cooking time, convenience in cooking process and create smokeless environment in the kitchen or reduce the volume of smoke produced during cooking against the traditional stove [1]. There is no international definition for the exact fuel savings that are necessary for a stove that can be considered as an improved stove. However, it is usually admitted that an improved stove should save about 50% of the biomass in field test (different from laboratory ones) and/or reduce considerably the phenomenon of Indoor Air Pollution due to bad combustion (production of smoke).

ICS is designed with modifications over traditional one with reduction in smoke emission and increased efficiency. The direct and indirect benefits of ICS include:

- Increased thermal efficiency
- The conservation of forest by cutback in firewood consumption
- Reduction in indoor air pollution and hence smoke-related health disorders
- Prevention of fire hazards
- Reduction of cooking time

Nepal is among the highest traditional fuel consuming country in Asia because of its higher dependence on traditional biomass fuels mostly, firewood, limited extend of charcoal and crops and animal residue. About 83% of the total population lives in the rural areas and around 4.5 million household residing in rural areas depend entirely on biomass energy, mainly firewood for heating and cooking purpose [2] In Nepal more than 90% of the households use very low efficient (7-10%) Traditional Cooking Stoves [3]. Use of biomass in poorly ventilated kitchen results in Indoor Air Pollution (IAP) and unsustainable use results in the emission of Greenhouse Gases. There are many successful and innovative technologies promoted in Nepal to reduce IAP among which ICS is widely used.

The research and development on the construction of new models of ICS have been undertaken by many organizations all around the world. Their primary objective for the stove is to maximize the efficiency. ICS have been a very good commodity to the villagers in Nepal as it has many new and exciting features. Apart from obtaining good efficiency, they are working on factors like ease of using stove, making it economical and aesthetically desirable and reliable.

For optimizing the efficiency of ICS, insulating firebricks were used as fabricating materials. The features of the insulating firebrick are:

- Light in weight
- Dimensions 230×114×75 in mm
- Bulk specific gravity (~0.70)
- High Insulation
- Thermal Conductivity (~0.26 W/m. K)

Overall features of Insulating Firebrick Stove are:

- High Insulation property
- Retains heat inside the stove
- High combustion efficiency
- Low fuel wood consumption
- Reduction in cooking time
- Ease of cleaning the stove

2. Methodology

Stove design was adapted from the single pot stove model developed by ISOLITE Corporation, Japan. Upgraded stove include two pot stove with different features like chimney on the secondary pot, introduction of grate on both combustion chamber, two feeding gates for better cooking time in secondary pot. The experiment proceeded by manufacturing of the stove and testing for the efficiency as well as flaws improvement.

For the purpose of testing different model, Water Boiling Test procedure was followed to calculate the thermal efficiency of stoves in various stages of modifications and improvement [5]. The water boiling test includes three phases. First was to boil water from cold phase of the stove, second was to continue using the hot stove to boil new sample of water and lastly to maintain the water at simmering temperature i.e. Cold Start, Hot Start and Simmering respectively. All tests were conducted on No wind condition with fuel Alnus Nepalensis, which is commonly used in Nepal for cooking purpose.

3. Description

A. *ICS Prototype 1*

First prototype was manufactured with the design consideration of chimney at the middle of the stove, two feeding holes with metal doors and slanted draft channel. The size of two pot hole is same.

Observation from the first stove manufacturing and testing:

- Maximum heat loss through chimney because of chimney position in the middle of stove body.
- Size of draught channel for pot hole 2 was small – backflow of heat smoke
- No. of Bricks used = 30 pieces

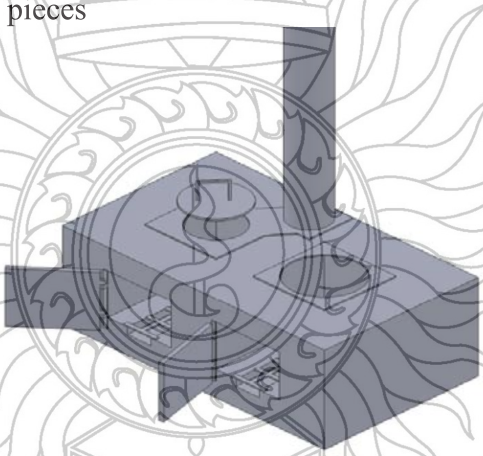

Figure 1. 3D CAD Model of Prototype 1

B. ICS Prototype 2

Second prototype is modified from the first one after identification of the flaws in the initial model. The new prototype size is smaller than Prototype 1. Size of primary pot hole larger than secondary pot hole. The combustion chamber is small. Chimney location shifted from middle of the stove to upper left corner of the secondary pot hole. The number of bricks used is less than in first prototype.

Observation from second stove manufacturing and testing:

- Due to small combustion chamber, there were difficulties in firing of wood
- Small feeding hole – difficulties in inserting wood
- Problem in continuous combustion and fuel feeding due to accumulation of charcoal.
- Hammering of Pot with chimney
- No. of bricks = 21

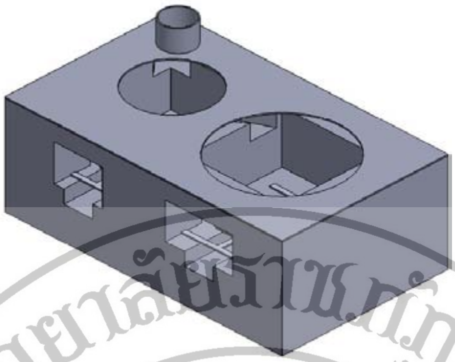

Figure 2. 3D CAD Model of Prototype 2

C. ***ICS Prototype 3***

Third prototype is the modified version of second prototype. The height of stove is 40mm more than second prototype. Diameter of primary pot hole changed from 240mm to 200mm. Distance between the chimney and secondary pot hole is increased to reduce hammering of the utensils with chimney. Door size is also changed to 160mm x120mm.

Observation from third stove manufacturing and testing:

- Acceptable size of feeding door, pot hole diameter and combustion chamber
- Height of stove at 268mm was suitable for sitting mode
- No hammering of cooking pot with chimney
- Satisfactory draught of flue gas in the system
- Chimney Diameter = 60mm
- Number of bricks = 25

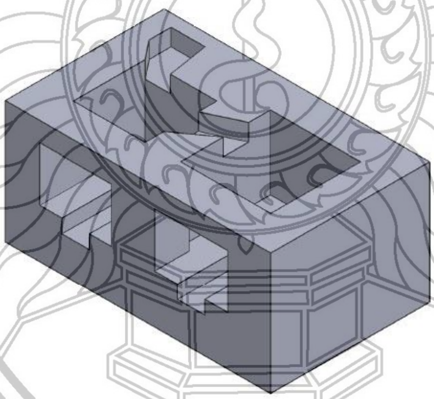

Figure 3. 3D CAD Model of Prototype 3

D. *ICS Prototype 4*

The final prototype is similar to prototype 3 as there were not major flaws in the design of the previous prototype. The cutting of bricks is changed for better strength, doors is added on both front openings and modification is done on the top plate for adjusting Nepali style cooking pots. The new dimension of the stove is (l x b x h) 578 x 346 x 268 in mm. Feed hole is (l x b) 160 x 120 in mm. Diameter of pot hole are 200mm and 160 mm. Chimney hole diameter is 60mm.

Observation from fourth stove manufacturing and testing:

- Metal Doors helpful in protecting bricks integrity at the feed hole openings
- Modified top plate was useful when stove was very closely handled
- Number of bricks = 25

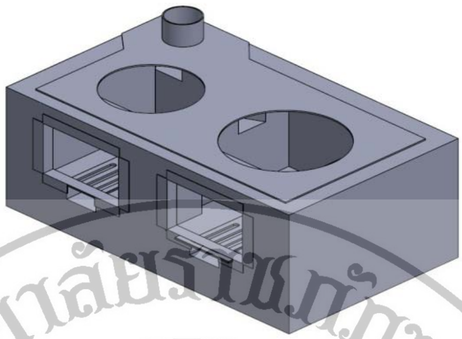

Figure 4. 3D CAD Model of Prototype 4

4. Results

Table

Water boiling test results

Prototype	Average Thermal Efficiency (in %)		
	Cold Start	Hot Start	Simmering
1	14	16	13
2	18	19	9
3	13	26	18
4	23	26	22

The maximum thermal efficiency was monitored in prototype 4 with efficiency of 23%, 26 % and 22% in Cold Start, Hot Start and simmering respectively under No wind condition. Fuel used is Alnus Nepalensis with moisture content 10 % in wet basis.

5. Conclusion

ICS development has been in the basic priority in the government policies of many underdeveloped country since years back, but the targeted achievement has not been achieved yet. There need to be more work done on the design of the more efficient stove, using local material and labour so that it will fulfill the need of targeted group of rural area. Improved cooking stoves are important in the rural areas of Nepal where large amount of biomass like fuel wood, cow dung, rice husk, etc. are used to fulfill daily energy need. As there is no 100% combustion of the fuels, the harmful gases will be emitted from the cook stoves. It is known that pollutants emitted from cook stoves cause serious indoor air pollution and have a negative impact on health of people. ICS reduces the particulate emission of harmful gases like CO2, CO, NO, etc. about 40-60% in comparison to the traditional stoves which help to minimize the infant mortality and morbidity rate. The reduction in use of traditional stove by using improved insulating stoves, therefore, will result in lower emissions of greenhouse gases in the atmosphere. Improved insulating cooking stove has got the thermal efficiency higher than that of improved and traditional stoves. The fire woods consumption is less. Proposed ICS model (prototype 4) is portable, safe, technically efficient and aesthetically desirable with easy construction process. The number of bricks used for construction was reduced in significant quantity which makes the model economical as well. Thermal efficiency in cold, hot and simmering test of water boiling test is 23%, 26 % and 22% respectively.

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