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AN IMPROVED COOK STOVE FOR DOMESTIC USE: A REVIEW

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Abstract: *The paper summarizes the working of cook stove and development that has been carried out to improve performance of cooking devices by adopting some measures. Traditionally used devices required more biomass fuel having low thermal efficiency. The research has been carried out in the way to improve thermal efficiency as well as focus given to complete combustion of biomass fuel with producing less ash content. The selection of material was done on the basis of availability and need of the cook stove design. Moreover, agricultural production in the country is increasing day by day with the agricultural mechanization, providing tremendous volume of agricultural residue every year. It was found that improved cooking devices more thermally efficient.*

Keywords: *Biomass, cook stove, thermal efficiency, combustion, gasification.*

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INTRODUCTION

The worldwide demand of energy is expected to rise dramatically in the near future. India requires more and more energy due to urbanization. Environmental factors also have an increasingly important role in shaping our future energy demands. The world requires cleaner and more sustainable energy sources to avoid pollution and climate change. Many alternative sources of energy are being proposed and evaluated such as solar power, wind energy, tidal energy and energy from biomass sources.

In India, energy requirement for cooking often has the biggest share of the total national energy demand and is normally meet mostly from biomass. Biomass refers to any organic material not derived from fossil fuels. It is renewable, widely available and uniformly distributed, carbon neutral and more economical than other renewable sources. By the year 2050, 15 to 30 per cent of world's primary energy could come from biomass. At present, about 11 per cent of primary energy needs are being met with biomass. The estimates of Ministry of New and Renewable Energy indicate that 32 per cent of the total primary energy use in the country is derived from biomass and more than 70 per cent of population is dependent on it for the energy needs. (Anon., 2010)

Community cooking normally refers to cooking of food for a group of about 25 or more persons in hostels, schools, community centers, hotels, rural/semi urban restaurants and road side dhabas, places of worship, residential monasteries, ashrams, caterers, suppliers of mid-day meals for schools etc. Community cooking is done using a coal-based traditional oven/furnace (bhatti) and direct burning of wood in ovens. Recently the use of LPG-based burners has also become a common practice in India. It is obvious that the use of a biomass gasifier based system for community cooking may provide an overall efficiency of about 40 per cent as compared to 8 to 20 percent from traditional oven/furnace, etc. Biomass gasifier-based community cooking systems are available in the thermal rating of 17.5 to 291kW (Tripathi*et al,*1999).

Fuels used in cookstoves

The selection of material was done on the basis of availability and need of the gasifier design. Moreover, agricultural production in the country is increasing day by day with the agricultural mechanization, providing tremendous volume of agricultural residue every year. Biomass fuels continue to representing the primary source of energy for more than 50% of the world population and amount to about 14% of the total energy global consumption. (McKendry, P., 2002)

Typical residues generated from agro industries are rice husk, coconut shell, corncobs, coir pith, tapioca waste, groundnut shells, coffee husk, etc. Bagasse from the sugar industry has a captive use for both heat and electricity. There are other wastes generated from industries where wood or woody like material is used as raw material; as in industries manufacturing paper, plywood, furniture, pencils, etc., where sawdust is available in abundance. Typically, 5– 20% of the feedstock remains as waste depending upon the industry. (Khardiwar, 2013)

Among several kinds of biomass, agricultural residues have become one of most promising choices. They are easily available and environmentally friendly. The biomass are available in different forms like rice husk, coffee husk, coir pith, jute sticks, bagasse, groundnut shells, mustard stalks, cotton stalks, bamboo dust, caster seed, palm husk, soybean husk and pigeon pea residue has been a handy and valuable source of heat energy all over the world in rural as well as the sub urban areas. During recent decades, biomass use for energy production has been proposed increasingly as a substitute for fossil fuels. There is large variability in crop residues generation and their uses in different regions of country depending on the cropping intensity, productivity and crops grown (Anon, (2006).

Technology development

Combustion of biomass in a cook stove is a variable process because thermodynamic efficiency of a cook stove depends upon a large number of factors such as stove design, fuel composition, vessel design, culinary practice, meteorological conditions and operational variables, such as fire tending and rate of heat supply, etc. Most of these factors are variable in nature and hence the thermodynamic efficiency of a cook stove is not a unique property of the cook stove. Thus, it has a limited utility and cannot predict the actual fuel consumption. The efficiency is a design tool rather than a means of predicting field performance of ICS. Gasification is the process of converting solid fuels, such as wood, agricultural residues and coal, into a combustible gas. A biomass gasifier consists primarily of a reactor or container into which fuel is fed along with a limited (less than stoichiometric, or amount required for complete combustion) supply of air. Heat for gasification is generated through partial combustion of the feed material. The resulting chemical breakdown of the fuel and internal reactions result in a combustible gas usually called producer gas. The heating value of this gas is in the range of 4-6 MJ/Nm, or about 10-15 % of the heating value of natural gas. Producer gas is a mixture of the combustible gases hydrogen (H), carbon monoxide (CO), and methane (CH) and the incombustible gases carbon dioxide (CO) and nitrogen (N); the actual gas composition may vary considerably depending on fuel type and gasifier design.

Natural draft Vs force draft cook Stove.

In traditional mud stove combustion, combustion happens almost as soon as volatilization around the solid fuel zone; this can lead to significant emissions of products of incomplete combustion. In contrast, force draft (FD) stoves and natural draft (ND) stoves tested were designed on the basis of principles of micro- gasification to improve combustion efficiency (Anderson, 2007). In micro-gasification stoves, air supply [from either fans (FD) or free convection (ND)] is partially supplied into the combustion chamber from primary small openings located at the bottom of the stove (Mukunda, 2011). The remaining air supply is channeled to the top of the combustion chamber (and preheated) through secondary small openings (Kar, 2012). Originally stage micro- gasifier based cook stove developed by Reed and co-workers developed a free convection-based gasifier stove and have subsequently discussed the development of forced convection-based gasifier stove force draft stove reduces smoke by up to 80-90%, significantly optimizes.

Working principle of cook stove

1. Primary air enters at bottom of fuel bed and moves upward.
2. Self-sustaining flaming pyrolysis front progresses downward through the bed of raw solid fuel leaving behind char above.
3. Initiate pyrolysis by lighting top of fuel bed with a fire starter material.
4. Mixing zone of rising hot gases with secondary air provided by external blower.
5. Then combustion occurs with a visible flame and usable heat.

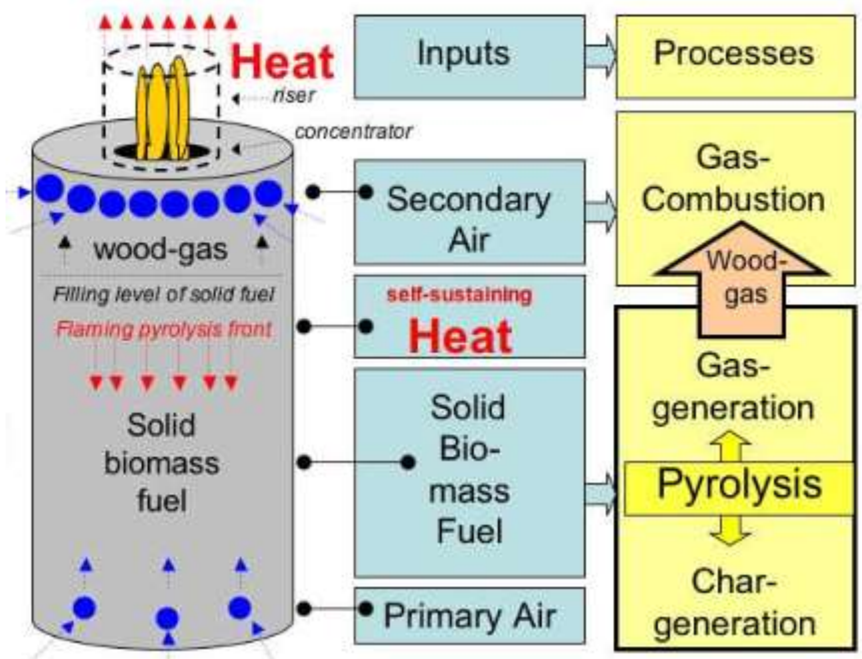

Fig 1: Working principle of cook stove (Roth C.,2011)

Cook stove operational procedure

1. Fuel is first loaded in the reactor and the lid is closed.Water is filled in the water seal.
2. The fuel is then ignited frombelow the grate using a flame torch through the ash pit door. As the fuel gets ignited and the gasification preceded the flame developed well at the bottom portion of the fuel, the flame is visible in the combustion chamber and smoke disappears from the chimney.
3. About five minutes later, the torch is removed and the ash pit door is closed. The ignition builds up slowly, and it takes about 20 minutes for the combustible gases (producer gas) to generate at the gas burner side.
4. The gases are then ignited in the gas burner by showing a flame through the secondary air holes in the burner.
5. Once the gas gets ignited, the flow of gas is continuous and smooth. The stove can operate continuously for several hours, until the fuel in the fuel chamber is used up.
6. Additional fuel can be loaded through the top of the fuel chamber to further extend its operation.

7. The ash scraper should be operated occasionally, to break up the ash accumulated inside the reactor. This will facilitate easy flow of fresh fuel from the hopper into the reactor.

Shutting down procedure

1. Feeding of the material into thereactor is stopped.
2. The gas is then allowed to burn as long asit is obtained from left over material.
3. The primary air entry intothe gasifier reactor is switched off by closing the sliding doorprovided at the bottom of the primary air inlet.
4. After the reactoris sufficiently cooled, its bottom ash door is opened and theash is removed.
5. The grate is cleaned again by scraper to makethe gasifier cook stove ready for the next operation.

Different designs of improved cooking devices

Pathgi and Sharma (2012) designed the stove works on natural cross draft mode with two pots for community cooking. The schematic diagram of biomass gasifier stove is shown Fig 2. The stove system comprises a gasifier stove, which includes the gas burner and a pot support to hold two pots. The biomass-fired gasifier stove consists of three main parts i.e. reaction chamber, primary air inlet and combustion chamber. Different parts of the stove could be attached together by bolts and nuts and welding mechanism. The biomass stove consists of well insulated cylindrical reactor, cast iron grate and adjustable air opening from bottom end. The reactor is a mild steel cylinder having inner diameter 30 cm, outer diameter 48 cm and height about 56 cm. in order to minimize heat losses critical insulation thickness of material from cement was held by mild steel anchors welded to the inner shell. Since the technology is adopted and using a standard material, in this case is not available most of the parts of the stove have been constructed using locally available material. The stove works natural draft gasifier stove. Primary air enters into the reaction chamber at one side, flows across the fuel bed and out in to the gas burner. Producer gas is generated while the primary air passes through the hot fuel bed, and the gas leaves the reaction chamber at the other side.

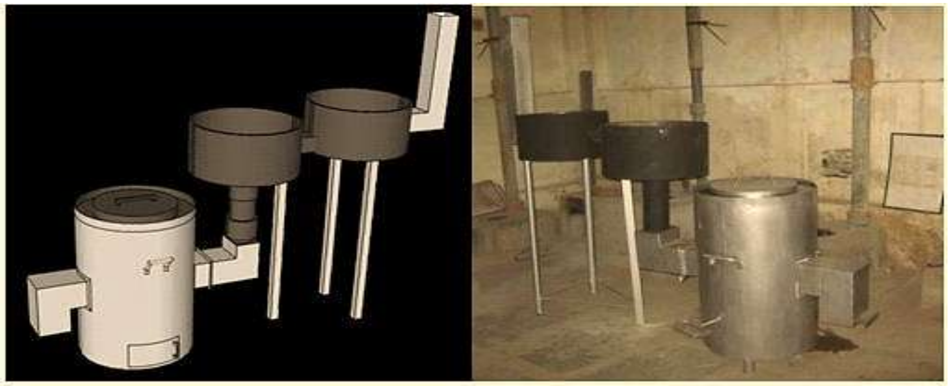

Fig 2: Schematic diagram of cross draft biomass gasifier cook stove

Panwar and Rathore, (2008) developed wood gas stove shown in fig 3 offers efficient applications, which make renewable energy devices user friendly and sustainable in the rural society (Khunita S. et al., 2000). The system was designed in which energy needed was calculated to cook food for family of 6 members which was found to be 15.8 MJ from which energy supplied was calculated with fixed fuelconsumption rate was found to be 1.45 Kg/hr. Reactor diameter and height was calculated found to be 14.3 cm and 31.5 cm respectively.

This type of stove has the potential to save fuel wood because it can work on a great variety of non-wood or waste-wood fuels. The combustion efficiency and heat-capture efficiency of stoves are better than efficiencies of open fires and stoves currently in use, resulting in the need for less fuel.

Fig. 3: Wood gas stove

Victor M. *et al.,* (2007) presents an energy evaluation of the Patsari cook stove an efficient wood-burning cook stove developed in Mexico.

The evaluation uses three standard protocols:

1. WBT which quantifies thermal efficiency and fire power.
2. The controlled cooking test which measures specific energy consumption associated with local cooking tasks
3. Kitchen performance test which evaluates the behavior of the stoves in-field conditions and estimates fuel savings.

Result showed that

1. The efficiency measured by stove was 30%.
2. The power of the devices varied between 6.4 kW to 9kW.

Points to be considered to improve combustion of fuel

1. Make sure there is good draft into the fire.
2. Insulate around the fire to help it burn hotter. A hotter fire burns up more of the combustible gases and produces less smoke.
3. Avoid using heavy, cold materials like earth and sand around the combustion chamber.
4. Lift the burning sticks up off the ground so that air can scrape under the sticks and through the charcoal.
5. Placing an insulated short chimney above the fire helps to increase draft and gives smoke, air, and fires a place to combine, reducing emissions.
6. Limit the cold air entering the fire by using as small an opening as possible. Small openings into the fire also force the cook to use less wood, which can be burnt more efficiently.
7. A certain amount of excess air is necessary for complete combustion. Preheating the air helps to maintain clean combustion. (Anon., 2002)

Performance carried out to evaluate the performance of cook stove

The performance evaluation of community cookstove carried out as per the test code IS 13152 (Part 1): 2013

1. Properties of biomass feedstock

i) Moisture content

ii) Proximate analysis

a) Fixed carbon%

b) Volatile matter%

c) Ash content%

iii) Calorific value

2. Physical properties of biomass

3. Temperature profile of cook stove

4. Burning rate and capacity (power output) of cook stove

5. Water boiling test for determination of thermal efficiency

6. Controlled cooking test (CCT)

7. Emission evaluation of cook stove

8. Economic feasibility of cook stove

Biomass cook stove for cooking applications

Gasification is the process of converting solid fuels, such as wood, agricultural residues and coal into a combustible gas. A biomass gasifier consists primarily of a reactor or container into which fuel is fed along with limited (less than stoichiometric, or amount required for complete combustion) supply of air. Heat for gasification is generated through partial combustion of the feed material. The resulting chemical breakdown of the fuel and internal reactions result in a combustible gas usually called producer gas. The heating value of this gas is in the range of 4-6 MJ/m^3, or about 10-15 % of the heating value of natural gas. Producer gas is a mixture of the combustible gases hydrogen (H_2), carbon monoxide (CO), and methane (CH_4) and the incombustible gases carbon dioxide (CO_2) and nitrogen (N_2). The actual gas composition may vary considerably depending on fuel type and gasifier design.

In India the realization for the use of biomass gasifier based cook stove has increased tremendously and the Government is also offering very good initiatives through the combined efforts of the Ministry of Agriculture and the Ministry of New and Renewable Energy.

CONCLUSIONS

Results obtained from different researchers it has been concluded that improved cook stoves are thermally more efficient as compared to traditional cook stove. It has been observed that the fuel consumption is less than conventional chullas. As the combustion occurs in a closed chamber fire hazards are minimum. In the traditional cook stove incomplete combustion occurs which can lead to significant emissions of hazardous gases which pollute the environment. Improved cooking devices significantly overcome such type of emissions.

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