Design and Development of Technology-Enabled Biomass Stoves

Bogala Konda Reddy, Korla Mohanakrishna Chowdary and Chintalapudi Pallavi

Abstract The gradual depletion of fossil fuels leads to gaining prominence on biomass fuels in rural and urban sectors. Biomass is a carbon-neutral fuel, and utilization of wood waste ensures sustainability. In today's scenario, biomass is the most efficient cooking fuel for rural households to attain sustainable development by reducing the usage of firewood. Improved version of biomass cooking stoves can reduce greenhouse emissions through enhancing the combustion process by providing means of sufficient air for combustion. The present work concentrates mainly on the design and development of biomass stoves with automation by using technology-enabled tools for controlling and operating the stove for better performance and also discusses various features of the designed and developed models.

Keywords Design · Development · Biomass stoves · Automation · Technology-enabled tools

1 Introduction

Cookstoves are commonly used for cooking and heating of food in households using solid fuels such as firewood, crop residue, dung cake and coal. As per the 2011 census of India, the fuels used for cooking in rural and urban areas are shown in Fig. 1. The traditional method of cooking on three-stone stoves gives the following disadvantages: (i) more emissions which cause health problems to women and children [1, 2], (ii) more fuel consumption which causes deforestation and (iii) more heat losses which cause less performance of stoves. In order to control

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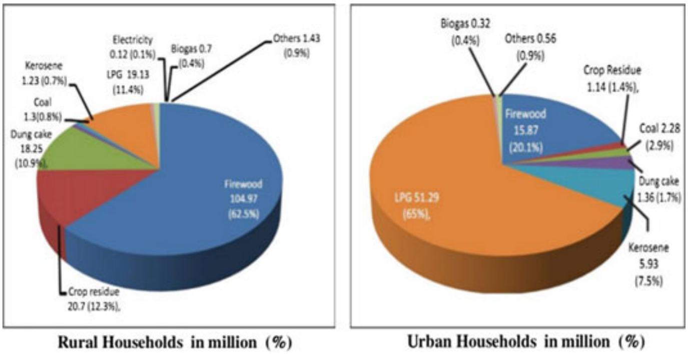

Fig. 1 Indian household energy scenario in rural and urban areas as per 2011 census of India

these disadvantages of traditional stoves, improved cookstoves (ICSs) came into picture.

Biomass is an organic matter that is derived from plant residues (agriculture and forest). Biomass fuel may be in the form of pellets or briquettes as shown in Fig. 2, generally a combination of agriculture (sawdust, wheat straw, corn stalk, rice husk, coconut shells, cotton stalks, maize straw, etc.) and forest wastes (firewood, wood chips, wood chunks, etc.). With gradual depletion of fossil fuels, once again biomass fuels are gaining prominence in the rural and urban sectors. Biomass is a carbon-neutral fuel, and utilization of wood waste ensures sustainability [3] as shown in Fig. 3.

The Indian standard for portable solid biomass cookstoves, IS 13152 (Part 1), was first published in 1991 [4] and revised in 2013 [5]. This standard covers requirements of different designs and types of solid biomass portable cookstoves for domestic and community/commercial applications. Natural and forced draught models of cookstoves were developed by various manufacturers for domestic and community applications, and those models were approved by Ministry of New and Renewable Energy (MNRE) on the basis of their performance testing as per IS

Fig. 2 Pellets and briquettes

Fig. 3 Carbon neutral cycle with biomass fuel

13152 (Part 1) 2013 specification. The approved models supplied by respective manufacturers/developers with stipulated performance parameters are given in Ref. [6] and also the models developed by various manufacturers are given in Ref. [7].

Out of the given models in Ref. [6], the automated models of biomass stoves were not developed. In view of developing automated biomass stoves, the present study concentrated on the design and development of biomass stoves with technology-enabled tools for controlling and operating the stoves for better performance.

2 Design of Biomass Stoves

Based on the instructions of the user and signals from sensors, the automatic control panel will give instructions to operating devices to control the flow rate of air, fuel feeding and opening and closing of the aperture of the combustion chamber for obtaining better performance. The flow chart for the automation of biomass stove is shown in Fig. 4.

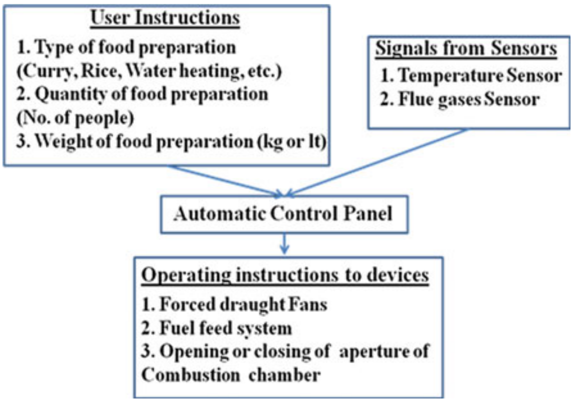

Fig. 4 Flow chart for automation of biomass stove

Two models of biomass stoves are designed in the modelling software as shown in Figs. 5 and 6. The proportionate dimensions of stove are taken as per specifications of IS 13152. The stove is designed in circular section and generally consists of combustion chamber, grate, ashtray at bottom, support at top for keeping cooking vessel and provision for circulation of air in combustion chamber. Apart from these basic parts of the stove, there are provisions designed in Model-I for automatic fuel feed system, iris mechanism for opening and closing of aperture of the combustion chamber and primary and secondary air circulation for combustion. Model-I is designed with some more provisions to provide sensors and to tap heat losses. In Model-II, more number of air circulation holes on combustion chamber is provided to increase the combustion performance.

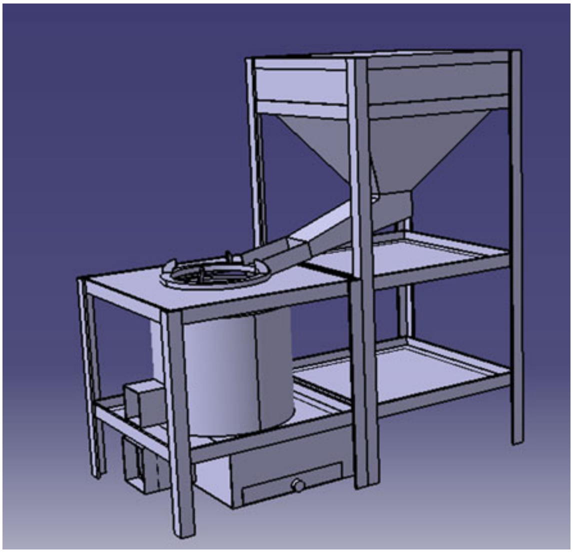

Fig. 5 Model-I of biomass stove (designed model)

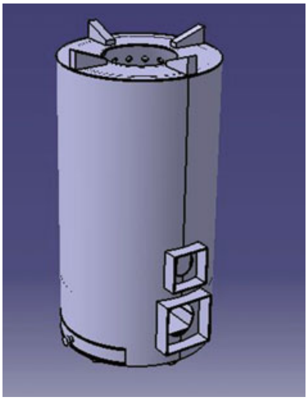

Fig. 6 Model-II of biomass stove (designed model)

In the design, measures are taken care to integrate all these components of stove with an automatic control panel. Based on the requirement of air for combustion, respective number of holes is provided on combustion chamber and the respective flow rate of fans is chosen for primary and secondary air supply.

3 Development of Biomass Stoves

Model-I: As per the design, the model is constructed with respective materials as shown in Fig. 7. The components of Model-I are shown in Fig. 8. The functions of these technology-enabled tools of biomass stove are as follows: (i) forced draught fans to supply primary and secondary air for better combustion and regulate the supply of combustion gases for cooking, (ii) TEG modules with heat sink to convert thermal energy into electrical energy by consuming waste heat loss from the stove, and the electrical energy will be stored in the battery for running variable speed forced draught fans based on requirement, (iii) automatic feeding mechanism to supply the required quantity of biomass for combustion, (iv) iris mechanism for variable opening and closing of aperture of combustion chamber based on the requirement of fire during cooking and also used to shut the fire after cooking and (v) an automatic control system to control or to operate the devices based on the instructions of the user and also to improve the performance of the stove.

Fig. 7 Model-I (constructed) of biomass stove

Fig. 8 Components of Model-I (from top left—combustion chamber, grate, thermal insulation and temperature sensor, rack and pinion mechanism, battery, primary and secondary fans, iris mechanism for closing and opening of aperture of combustion chamber, control panel, flue gas sensor, thermoelectric generator (TEG) module with heat sink, hopper and ashtray)

Model-II: As per the design, this model is constructed with respective materials as shown in Fig. 9. The components of Model-II are same as Model-I except the combustion chamber to which more number of holes are provided for more circulation of air for better combustion.

Fig. 9 Model-II (constructed) of biomass stove

The programme was developed and embedded in the control panel board. Based on the instructions of the user for the type of food preparation, the control panel will give instructions to devices to supply a respective quantity of pellets into the combustion chamber and respective speed of air through primary and secondary fans. Hence, the control of combustion takes place effectively. Based on water boiling test, these two models have recorded the thermal efficiency of 35–40%.

4 Conclusions

In the present work, two models of automated biomass stoves were developed with technology-enabled tools to improve the performance of stoves. The following components were used as technology-enabled tools: (i) forced draught fans, (ii) automatic pellets feeding mechanism, (iii) iris mechanism and (iv) an automatic control system. The designed and developed models of stoves have been recorded 35–40% thermal efficiency.

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