Chapter–6
Summary and Conclusions

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This Chapter summarizes and concludes the present PhD research work titled "Development of a fuel efficient multi-purpose biomass stove" which is presented in five different chapters in this thesis. The research gaps which motivated the present work is also briefly highlighted before summarizing the major outcomes

6.1 Background

Biomass fuelled cook stove is a pre-dominantly used household technology almost all over the world except few pockets of developed region. Despite of its inherent limitations of solid fuelled cook stove, its dominance is expected to remain for some period to come due to several reasons in its favor. Based on a comprehensive global overview of prevailing improved biomass cook stove and required user's features, there is a need for development of multifunctional biomass cook stoves. The current research was undertaken to develop a multifunctional biomass fuelled stove which can perform multiple pot cooking and multifunctional activities of baking, drying and space heating.

6.2 Steady state heat transfer modeling of biomass cook stove

Conventionally the performance of a biomass stove is determined using laboratory and field based test procedures, the repetitive uses of which are costly and time consuming. A steady state heat transfer model is developed for a typical natural draft stove to have a realistic representation of the working of the stove using fundamental heat transfer principles. Ignition front velocity, power delivery, time to boil and efficiency for the biomass cook stove have been modeled. The quantification of heat loss components particularly heat lost through flue gas, heat lost in pre-heating air and heat lost in unburned fuel have been useful to identify the appropriate features for improvement of an improved cook stove. Further the requirements of multifunctional features to fulfill the user's needs and to suit the local customs become useful to conceptualize the Multifunctional Biomass Fuelled Stove (MBFS).

This identification of major heat loss components of a typical biomass cook stove motivated to incorporate appropriate features and subsequently update the modeling

technique with added features and finally integrate the features to develop MBFS which is described below.

6.3 Development of a multipurpose improved cook stove

Multifunctional, improved performance and user friendly design have been the driving elements to conceptualize and improved cook stove. Several new features with corresponding design elements (regulated air supply, provision of secondary air supply, recovery of waste heat, reduced thermal mass, pot envelop, better combustion chamber, air preheating, multifunctional applications, multiple pot applications, durable, portable, stable and uninterrupted use) have been identified to design MBFS. The predicted improved performance (45%) and added benefits (option for varying output power, multifunctional applications, multiple pot cooking, faster cooking and cleaner cooking) of the 4.5 kW stove estimated through heat transfer modeling could be subsequently confirmed through series of standard laboratory tests (BIS and WBT).

The current research is further extended to investigate the prospect of technology (MBFS) transfer. Status of newly developed stove in terms of thermal performance among the prevailing improved cook stove have been investigated. Further the economic analysis based on a potential achievable rural enterprise for manufacturing of MBFS has been done which is presented below.

6.4 Planning technology transfer of Multifunctional Biomass Fuelled Stove

Thermal performance results available in literature for BIS procedures as well as WBT procedures have been considered for this analysis. The test results of single pot options of MBFS have been used for BIS tested stoves whereas performance results of multiple options have been used to compare the WBT tested stoves. The emission testing could not be performed for MBFS which is considered as limitation of current research. However provision of innovative mode of air supply for combustion is expected to minimize the emissions or reduce the incomplete combustion. Overall the MBFS outperformed most of the prevailing stoves used for comparison in present study in terms of thermal efficiency.

The prospect of a rural enterprise based on manufacturing and subsequent marketing of MBFS has been examined, conceptualizing a rural manufacturing unit with annual

production capacity of 7300 units of MBFS. The manufacturing capacity is assumed based on an expected demand of typical rural population in India. The abundant availability of cheaper biomass fuel and demand for space heating during cold season is expected to induce preference in such regions. Positive NPV for a 10 year project period based on current economic parameters (discount rate, initial cost, insurance cost, periodical cost, operational cost and inflation rate) and unit market price (₹ 2200) has been in favor of possible transfer of technology as a rural enterprise.

6.5 Conclusions

The present research work can be concluded as below:

- The heat transfer components were delineated and estimated based on operating parameters using a steady state heat transfer model.
- Waste heat components in a biomass cook stove have been identified.
- A new multifunctional biomass cook stove has been conceptualized using features addressing waste heat recovery, multifunctional applications and multiple pot cooking with an updated steady state heat transfer model
- A 4.5 kW Multifunctional Biomass Fuelled Stove is developed and tested for its performance.
- The potential for technology transfer of Multifunctional Biomass Fuelled Stove is accessed based on comparative performance and economic analysis.

6.6 Future works

The present research work has attempted and succeeded in developing a steady state model for solid fuelled combustion device and used it to develop a multifunctional stove. However works on determining the emissions liberated remains limited in the present research. Therefore researchers could perform works related to emission measurements both in laboratory as well as for actual conditions.

In addition to the above the developed MBFS technology was not implemented in the rural households. Implementation of which would have provided vital information on user needs and satisfaction.