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Stovesim: An open source optimization software package for wood-fired biomass cookstoves

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Abstract

The use of solid biomass as a fuel source for primary cooking is common to more than half of the world’s population. Household air pollution (HAP) as a product of utilizing biomass as a fuel while cooking indoors was estimated to have caused 2.8 million deaths alongside 85.6 million disability-adjusted life years in 2015—disproportionately affecting women and children in low-to-middle income countries. Moreover, combustion of biofuel is estimated to contribute to 20% of worldwide carbonaceous aerosols which have significant negative health impacts related to air quality and a strong influence on our global radiative balance. Despite efforts to improve biomass cookstove technology, modern technology remains an inefficient cooking and heating source due to improvement methods being based primarily on experimental observation and derived “rules of thumb”. More recently, the use of computational fluid dynamics (CFD) has been encouraged as a means of design advancement by bringing to light the complex and interconnect thermophysical processes within the modern cookstove. Moreover, integrating CFD into the design stage of cookstove development can reduce the dependence on costly and time-consuming experiments. The objective of this work is to present *StoveSim*, an open-source fluid dynamics simulation and optimization software package that utilizes OpenFOAMTM solvers. The work will include assumptions and methodology applied in the CFD, usage instructions, and results of a preliminary case study. Moving forward, the software will be installable with an open-source license for use and further development within the biomass cookstove community.

Keywords: Biomass, Cookstove, Computational Fluid Dynamics, Software Development

Nomenclature

Place nomenclature section, if needed, here. Nomenclature should be given in a column, like this:

α alpha

β beta

1. INTRODUCTION

Biomass is used as a fuel source for primary cooking by more than half of the world population. Burning biomass indoors causes household air pollution (HAP) which is estimated to have contributed to 2.8 million deaths and 85.6 million disability-adjusted life years in 2015; these estimates were found to disproportionately affect women and children in low resource countries [1]. In addition to detrimental health effects, combustion of biomass fuel contributes to 20% of carbonaceous aerosols which has a strong influence on Earth’s radiative balance [2]. Over the past thirty years, significant research efforts have been made to design affordable biomass cookstoves to disseminate to the developing nations most reliant on biomass combustion. A handful of design features have been attributed to improved cooking performance such as addition of a chimney and XX (what else?) (cite this). Despite the research efforts made, biomass cookstoves remain detrimental with respect to user health and climate change contribution.

Much of the early progress in cookstove design was derived by experimental observation and “rules of thumb”. More recently, experimental work has been coupled with computational methods to, first, better understand physical phenomena that yield a cleaner cookstove, and second, take a step towards predictability and optimization of cookstoves. Computational fluid dynamics (CFD) has been identified as a robust method to augment current understanding of cookstove performance as it relates to specific geometric and operational parameters.

Introducing forced-draft oxidizer-control has been identified as a promising design feature to improve efficiency of biomass cookstoves, thereby limiting the detrimental impacts of current technology (**add some citations here—Uws, that one berkely**). More specifically, adding small electronic fans in cross-flow

1. **MATERIALS AND METHODS**

All materials and methods that have been used in the work must be stated clearly. Subtitles should be used when necessary.

**2.1 Software Usage**

Subtitles should be bold but not all-capped.

**2.1.1 User Definitions**

To precondition the simulations, users are required to declare a series of input parameters in a local *input.yml* file; Table X below presents the full list of required user-definitions, units, and allowable limits. Note, the parameter names are declared with underscores in the *input.yaml* file, and will prevent the package from running properly if edited by the user.

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The variables used to define the design space, respect to the secondary forced draft are the

1. **RESULTS AND DISCUSSION**

Place results and discussion here. *Authors should make sure that all tables, graphics, and equations fit within the columns and do not run into the margins.* All figures, graphs, tables, etc. should be numbered. Ensure that all text is in black and that there is no highlighted text.

**FIGURE 1:** PERCENTAGE OF PAPERS THAT SHOULD BE FORMATTED CORRECTLY  
  
Equations should be numbered (1), (2), (3), and so on, with the number flush right in the column and a space before and after the equation, like this:

(1)

1. **CONCLUSION**

Place 3-4 line conclusion here.

**ACKNOWLEDGEMENTS**

Place any acknowledgements here.  
  
**REFERENCES**

[1] Thakur article, First Name. *The Name of the Book*, 2019

[2] Roden et al., 2006; Yttri et al., 2009