A detailed computational model of a wood-fired cookstove for determining the effect of geometric parameters on thermal efficiency and emissions

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Abstract

Improving the thermal efficiency and reducing harmful emissions of biomass-fuelled cookstoves has long been of interest to researchers. Millions of families in India and developing countries worldwide use simple wood-fired stoves for cooking. The emissions from the incomplete combustion of wood, including soot, volatile hydrocarbons and carbon monoxide all have health effects, which become evident only in the long term. Thus there is a global challenge to improve cook stove design to reduce harmful emissions without reducing the efficiency. The development of new designs of cook stoves, which produce less emissions, is imperative and a better understanding of biomass combustion inside the stove is essential for improvements in stove design. The present work focuses on the development of a detailed CFD model of a natural draft cook stove, using the commercially available CFD software ANSYS FLUENT 19.3.

A reduced reaction model has been developed, which represents the combustion of pyrolysis gases from the wood. Solid phase combustion of biomass is modelled as a constant heat source, based on the equivalent calorific value. The fluid dynamics of the gas phase are represented by the realisable k-ε turbulence model. Heat transfer by radiation is also important and thus is modelled using the discrete ordinates (DO) approach. The computational domain used to represent the cook stove includes not only the stove itself, but also its immediate exterior surroundings. This computational domain was discretized using a polyhedral mesh, with around 1.5-2 million cells. The 3D steady state model predicts the temperature distribution inside the cook stove during combustion of the wood. The effect of the following geometrical parameters on the stove performance were studied in the present work: size of main air inlet, standoff distance of the cooking pot from the stove, stove ground clearance and size of the wood logs. The optimum frontal area of the main air inlet was found to be 8100 mm^2, which maximises the heat transferred to the pot.