Chapter 19
Solid Biomass Combustion Simulation Using OpenFOAM

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ABSTRACT

Burning fossil fuels is the primary cause of global warming, with profound impacts on health, ecosystems, and infrastructure. Transitioning to renewable energy sources is crucial. Biomass, a key renewable source, offers benefits like carbon neutrality, lower emissions, and steady generation. Its use has surged, ranking it as the fourth major energy source globally. Combustion is the most common method for biomass energy; however, inefficiencies persist. Therefore, enhancing combustion efficiency is critical for emissions reduction. Computational fluid dynamics (CFD) models offer a promising avenue for optimization. OpenFOAM, an open-source CFD software, presents a valuable tool for simulating biomass combustion, yet its application in this field remains limited. This chapter proposes a methodology for biomass combustion simulation in OpenFOAM using "coalChemistryFoam" solver, offering a detailed examination of the current state of the field, the mathematical model within OpenFOAM, and the simulation procedure.

DOI: 10.4018/979-8-3693-3200-9.ch019

INTRODUCTION

The combustion of fossil fuels for energy generation remains the primary contributor to global warming, with far-reaching consequences for human health, ecosystems, and infrastructure worldwide (Intergovernmental Panel on Climate Change (IPCC), 2023). Consequently, there is a pressing need to transition to renewable energy sources that offer reduced environmental impact while meeting society's energy demands. One of the most important renewable sources is biomass because it has several advantages, such as neutral carbon emissions (García Fernández, 2014; Rodríguez, 2014; Susmozas, 2015) (Demirbas et al., 2009; Yin et al., 2008), lower emissions than traditional fuels (Demirbas et al., 2009; Dinh Tung et al., 2009; Karim & Naser, 2018b), generation without the intermittency problems presented in wind and solar energy (Dernbecher et al., 2015; Sher et al., 2020), employment and development in rural areas (García Fernández, 2014) and use of waste materials from other processes (García Fernández, 2014) (Gómez et al., 2019).

In recent decades, the utilization of biomass as an energy source has surged, (Khodaei et al., 2015), positioning it as the fourth major energy source globally, following coal, oil, and natural gas (Shah & Venkatramanan, 2019). Combustion remains the predominant method for converting biomass into energy, (Bhuiyan & Naser, 2015) (Bhuiyan et al., 2016), particularly notable when utilizing residual biomass from other processes, thereby mitigating deforestation and land use conflicts. However, there are still inefficiency problems in biomass furnaces that make the process uncompetitive (Szemmelveisz et al., 2009; Yang et al., 2004). Addressing these inefficiencies is critical for enhancing combustion efficiency, leading to significant reductions in emissions and fuel consumption. Studies have demonstrated that even a 1% increase in biomass-fired power plant efficiency can result in a 3% reduction in CO_2 emissions (Bhuiyan et al., 2016).

Computational Fluid Dynamics (CFD) models offer a promising avenue for optimizing solid biomass combustion equipment, enabling faster, safer, environmentally friendly, and cost-effective studies compared to conventional experimental approaches. Consequently, there is a growing motivation in the development of this type of application worldwide, as seen in the review works of Dernbecher et al. (Dernbecher et al., 2019), Karim and Naser (Karim & Naser, 2014), Khodaei et al. (Khodaei et al., 2015), Bhuiyan et al. (Bhuiyan et al., 2016) and García et al. (G. García Sánchez et al., 2020; G. F. García Sánchez et al., 2021). Despite its potential, the field is still in its developmental stage, owing to the inherent complexity of the combustion process, necessitating multiple submodels and significant computational resources for simulations (Dernbecher et al., 2019).

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