Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 110 (2017) 390 – 395

Energy Procedia

1st International Conference on Energy and Power, ICEP2016, 14-16 December 2016, RMIT University, Melbourne, Australia

Numerical modelling of solid biomass combustion: difficulties in initiating the fixed bed combustion

Md Rezwanul Karim, Jamal Naser*

Swinburne University of Technology, Hawthorn, VIC 3122, Australia.

Abstract

Bio mass is a renewable energy which has become an important fuel to produce thermal energy or electricity. It has no adverse effect on environment as it reduces carbon dioxide emissions. Biomass combustion is a difficult phenomenon due to its properties with less carbon, more volatile matters and lower calorific value. Fixed bed combustion is a useful technique for thermal conversion of solid biomass fuels as this can fire up a broad range of fuels with different properties and requires less fuel preparation. But due to complex solid combustion mechanism and inadequate knowledge on process the development of such combustion system is limited. Numerical modelling of this combustion system has some advantages over experimental analysis. But developing a complete model for this type of combustion system is a challenge. Due to its characteristic properties, modelling of biomass combustion has to overcome many difficulties. One such problem is initiating the combustion in numerical modelling. The usual way to model biomass combustion is to divide the system in to two phases namely solid phase and gas phase. Modelling the solid phase of this combustion system requires the major effort. In this work, a detailed analysis of difficulties occurred in initiating the biomass combustion has been presented. A complete three-dimensional numerical model is used for transient analysis of fixed bed biomass combustion. The bed is considered as a porous medium and solid phase of the combustion is characterised by using sub models with several variables in a commercial CFD code.

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.

Keywords: Numerical model; Biomass combustion; Fixed bed combustion

* Corresponding author. Tel.: +61 3 9214 8655; fax: +61 3 9214 8264.
E-mail address: jnaser@swin.edu.au

Peer-review under responsibility of the organizing committee of the 1st International Conference on Energy and Power.
doi:10.1016/j.egypro.2017.03.158

1. Introduction

Biomass has become an important energy source which can produce thermal energy and electricity with less emission because it is a carbon dioxide-neutral energy source. But the conventional furnaces are not efficient for biomass combustion. The combustion of solid biomass is a complex phenomenon as biomass consists more volatile matter, less carbon. To develop an efficient combustion system, it is very important to improve knowledge on the mechanisms and processes involved in the combustion system. There are very few biomass combustion systems available now and fixed bed combustion is one of them [1]. In fixed bed combustion the thermal conversion of biomass occurs in the bed and the flammable volatiles burn inside the combustion chamber. Experimental investigation of this system is difficult due to limited access and inhomogeneity inside the bed. Numerical modelling [2-6] of this combustion system are very helpful to analyse different working conditions combining theoretical model and experimental data. A comprehensive review of numerical modelling for biomass combustion [7] presents the current modelling methodologies, modelling of various sub-processes of solid conversion, heat and mass transfer etc. A basic modelling approach divides the system in to solid phase and gas phase. Gas phase has been modelled using commercial CFD code for various combustion systems. While modelling the solid phase and its linkage with the gas phase remains difficult. Different bed models has been completed by considering the bed as zero dimensional, one dimensional, two dimensional etc. [8-14]. A complete three-dimensional model for fixed bed biomass combustion is still under development. There have been difficulties to initiate the combustion in numerical simulation as biomass is different from other fuels by characteristics. In this study a 3D CFD model for biomass combustion in fixed bed furnace has been used to analyse the problems occurred during the start of the combustion in numerical modelling.

Nomenclature

A_v	area-volume ratio (m^{-1})	S_S	solid energy source term (Wm^{-3})
C_p	specific heat ($J\ kg^{-1}\ K^{-1}$)	T	temperature (K)
d_{eq}	equivalent diameter of particle (mm)	ε	solid fraction (–)
h	convection coefficient ($W\ m^{-2}\ K^{-1}$)	ϵ	emissivity (–)
k	thermal conductivity ($W\ m^{-1}\ K^{-1}$)	t	time (s)

2. Description of numerical model

In this work a 3D CFD model of biomass combustion in fixed bed furnace has been used for the numerical solution of the solid and gaseous phase and the interface between these phases. Available CFD codes can’t simulate the solid phase of biomass conversion but it allows coupling of user defined subroutines. Here, CFD simulation has been conducted using a commercial CFD code, AVL Fire 2014. To model the solid phase of combustion, cell based user defined subroutines are written in FORTRAN and coupled to AVL Fire for different sub-processes of solid conversion like drying, devolatilisation, char combustion and heat and mass transfer. Several scalar variables for solid phase are defined such as solid temperature or fuel temperature (TS), solid fraction (ε), densities of solid components (ρ) and particle diameter (dp). Among the main steps of solid conversion, drying, devolatilisation and char generation are controlled thermally while char consumption can be controlled both kinetically or diffusionally. Moisture evaporation is considered to occur at 373.15K. Assumptions of this modelling includes consideration of porous fuel bed as a disperse medium, variation of solid density during drying, devolatilisation and char reactions while variation of solid fraction during the char reaction only. Transport equations of the solid variables and different rates of the solid fuel conversion steps (drying, devolatilisation and char combustion) are well established and can be found in [15,16].

Gas phase conservation equations like energy, momentum, continuity, turbulence has been solved using AVL Fire’s built-in algorithm. The second-order upwind method is used for discretisation and standard k-epsilon model is used to consider the turbulence effect. A source is added in the momentum equation to count the effect of the porous bed on the gas flow [17]. Gas phase reactions are partial oxidation of benzene, methane and hydrogen to carbon monoxide from devolatilisation. Heat and mass transfer plays an important role in defining the linkage between solid and gas phase. Gas phase heat transfer can be modelled by the available CFD code but heat transfer for the solid phase and the