EFFECT OF COAL PARTICLE SIZE, AIR VELOCITY AND TEMPERATURE ON TRANSIENT PULVERIZED COAL COMBUSTION

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Abstract

Transient pulverized coal combustion is a complex process influenced by multiple interacting parameters, notably coal particle size, air velocity, and ambient temperature. This study investigates the combined effects of these variables on burnout time and temperature. A series of transient simulations were performed to analyze how variations in particle size affect temperature and residence time while changes in air velocity occur. Additionally, the influence of initial air temperature on combustion characteristics was examined. Results reveal that smaller particles and higher temperatures significantly enhance burnout due to improved surface-area-to-volume ratio and faster reaction kinetics. The combustion rate diminished as the diameter of pulverized coal particles increased. The findings contribute to a deeper understanding of the transient behavior of pulverized coal combustion.

Keywords: Pulverized coal combustion, transient behavior, particle size, inlet air characteristics

Introduction

Coal is the most plentiful and extensively distributed fossil fuel. It will keep playing a significant role in the global energy system for a very long time given the drying up of oil and the immaturity of renewable energy technologies [1,2]. Around 50% of the world's total coal reserves are low grade coal with high emission potential [3]. The shift to low-carbon energy systems is rendered more difficult because coal is the primary source of CO_2 emissions and the major source of electricity generation [2]. Combustion methods have advanced significantly, with pulverized coal (PC) combustion being the most common. Preparing coal for combustion is key to the realization of clean coal technology [4]. The ignition properties of the coal particles are crucial variables in the combustion system for pulverized coal. Enhancing coal particle ignition performance helps increase combustion efficiency and lower pollutant emissions [5].

Computational fluid dynamics (CFD) is preferred as an essential tool to analyze the pulverized coal combustion process in a time-dependent manner. Recent research has focused on different combustion models to simulate pulverized coal combustion using the RANS (Reynolds-averaged Navier-Stokes) method. The Species Transport (ST) approach is also commonly utilized to achieve high accuracy solutions [1]. Therefore, in recent years, significant efforts have been made to examine transient behavior and combustion processes of the pulverized coal in various applications. Yadav et al. reviewed different aspects of pulverized coal combustion including new combustion and emission reduction technologies [6]. Wen et al. examined multi-dimensional and transient effects on flamelet modeling for pulverized coal combustion [1]. Zhang et al. investigated pulverized coal ignition modes and characteristics for transient coal combustion [5]. Zhuo et al. developed a 3D CFD model to understand pulverised coal combustion characteristics on an ironmaking blast furnace [7]. Cui et al. handled a 2D gasification region with porous media approach using a new mathematical model of unsteady chemical reactions [8].

However, few investigations have been performed on the transient flow in porous media that connects the mass and heat transfer processes of the pulverized coal combustion reactions. Considering all these aspects, this study investigated the key factors affecting pulverized coal combustion. Coal particle diameter, inlet air velocity and temperature were investigated on a two-dimensional combustion region as a transient simulation process.

Methodology, Modeling and Simulation Conditions

In this study, the time-dependent combustion of pulverized coal in a channel was investigated with the Species Transport Model on CFD [9,10]. Ignition through an external source was realized, and air flow was sent to the coal in a fixed channel. The combustion characteristics were investigated as a function of temperature. Table 1 shows the parameters of the study.

Table 1. Parameters of the study

No	Coal particle dia. (μm)	Air velocity (m/s)	Air temperature (K)
P1	50	1	298
P2	50	5	298
P3	50	10	298
P4	10	5	298
P5	50	5	298
P6	100	5	298
P7	50	5	298
P8	50	5	373
P9	50	5	523

Results and Discussions

This study presents a time-dependent 2D numerical CFD model of the pulverized coal combustion process. Combustion rate and temperature variations concerning coal particle diameter, air inlet velocity, and temperature variables were evaluated. Fig. 1 depicts the variation of temperature in respect to coal particle diameters (d_p).

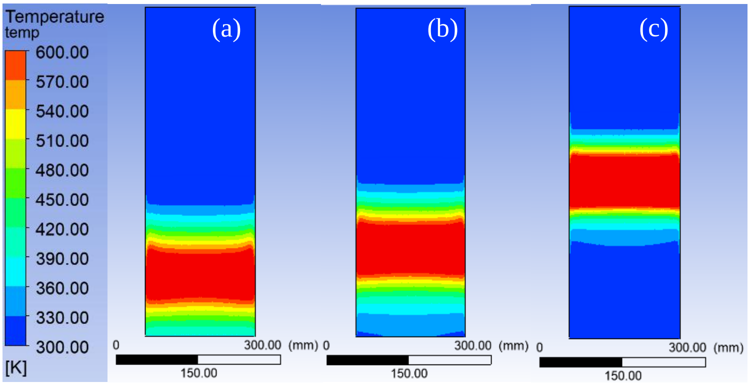

Figure 1. Temperature variation for d_p a) 10 μm, b) 50 μm, c) 100 μm at t=20 s.

The combustion rate decreased with the increase in pulverized coal particle diameter, which is directly related to the decrease in the amount of O_2 between the particles. Fig. 2 shows the midpoint temperature of the channel for different parameters.

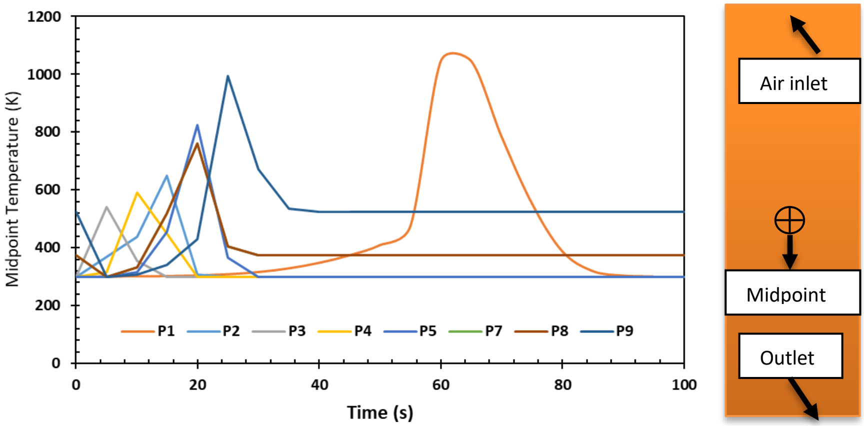

Figure 2. Midpoint temperature variation with respect to time for various parameters

It reveals that peak midpoint temperatures were reached at distinct temporal intervals depending on the parameters. Elevated air velocities accelerated combustion kinetics, increasing maximum temperatures at earlier stages. Similarly, larger coal particle sizes corresponded to prolonged combustion durations.

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