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STEAM BOILERS, POWER-GENERATING FUEL, BURNERS, AND BOILER AUXILIARY EQUIPMENT

Modeling the Burnout of Solid Polydisperse Fuel under the Conditions of External Heat Transfer

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Abstract—A self-similar burnout mode of solid polydisperse fuel is considered taking into consideration heat transfer between fuel particles, gases, and combustion chamber walls. A polydisperse composition of fuel is taken into account by introducing particle distribution functions by radiuses obtained for the kinetic and diffusion combustion modes. Equations for calculating the temperatures of particles and gases are presented, which are written for particles average with respect to their distribution functions by radiuses taking into account the fuel burnout ratio. The proposed equations take into consideration the influence of fuel composition, air excess factor, and gas recirculation ratio. Calculated graphs depicting the variation of particle and gas temperatures, and the fuel burnout ratio are presented for an anthracite-fired boiler.

Keywords: modeling, combustion, solid fuel, polydisperse composition, distribution function, combustion modes

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One of the methods used to fire natural solid fuel (coal) in furnace devices is its combustion in pulverized form. In this case, aerosuspension is supplied to the burners, which consists of a mixture of air and polydisperse pulverized coal. Combustion of pulverized fuel is a complex set of physicochemical phenomena, such as heat transfer between particles, gases, and enclosing surfaces, release of moisture and volatiles in the course of heating, combustion of volatiles and coke residue accompanied by a multitude of various reactions and intense mass transfer, conversion of the fuel mineral part, etc. These processes may run either sequentially in time or concurrently with each other and have a strong influence on each other. In this connection, those carrying out a theoretical analysis face the need to simultaneously consider equations describing the motion of gases with particles, heat transfer between particles, gases, and walls, chemical kinetics that takes into account, apart from coke residue combustion, also the release and combustion of volatiles, etc. Since some processes are still poorly understood, we can state that it is almost impossible to construct an exact mathematical model, and an attempt to decrease the number of simplifying assumptions will inevitably result in obtaining an excessively complicated model. Thus, we should take only those simplifying assumptions that do not have an essential effect on the main processes and that will allow us to obtain satisfactory agreement between calculation and experiment.

A polydisperse composition of fuel gives rise to certain difficulties in calculating a pulverized coal flame. The sizes of pulverized fuel obtained in milling coal may differ from one another by as mush as one or two orders of magnitude. Since the intensity of heat transfer between particles, gases, and enclosing surfaces, release of volatiles, and other processes depend on the size of particles, particles belonging to different fractions burn under different conditions. Fine fractions are heated and ignited more rapidly than large fractions, thus increasing the general temperature level in the system and consuming part of oxidizer. It should also be pointed out that both sizes of particles and their quantity vary during the combustion process.

Matters concerned with studying the combustion of polydispersed solid fuel systems were addressed in many works. In some studies [1, 2], polydispersed composition was taken into account by introducing a conditional "monodispersed" system averaged according to the initial distribution function based on the Rosin–Rammler law, whereas other researchers [3] took polidispersity into account by subdividing a system into certain number of fractions with finding the average size within each of them. The authors of [3] stated and solved problems concerned with analyzing the ignition and burnout of both individual particles and "monofractions" at short process periods. To this end, systems of equations written for each fraction were solved numerically.

Application of a statistical approach to solving the problems concerned with combustion of polydispersed pulverized coke, central to which is solution of the kinetic equation for the particle distribution function by radiuses [4, 5], made it possible to boil down the problem to solving the equations for the particle size averaged over the distribution function.