ISSN 0040-6015, Thermal Engineering, 2013, Vol. 60, No. 11, pp. 775–782. © Pleiades Publishing, Inc., 2013.
Original Russian Text © A.P. Baskakov, V.A. Munts, E.Yu. Pavlyuk, 2013, published in Teploenergetika.

Transients in a Circulating Fluidized Bed Boiler

A. P. Baskakov, V. A. Munts, and E. Yu. Pavlyuk

Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia

Abstract—Transients in a circulating fluidized bed boiler firing biomass are considered. An attempt is made to describe transients with the use of concepts applied in the automatic control theory. The parameters calculated from an analysis of unsteady heat balance equations are compared with the experimental data obtained in the 12-MW boiler of the Chalmers University of Technology. It is demonstrated that these equations describe the transient modes of operation with good accuracy. Dependences for calculating the time constants of unsteady processes are obtained.

Keywords: fluidized bed, circulating fluidized bed, transients, biomass, boiler, circulation ratio, temperature

DOI: 10.1134/S0040601513110025

Operation of circulating fluidized bed (CFB) boilers is described in detail in many individual publications, as well as in monographs, e.g. [1–3]. However, transients in such boilers are addressed only in a few works [4–6]. These processes need a more detailed study, in particular, for development of automatic closed-loop control systems. An attempt is made in this work to describe transients using the automatic closed-loop control analysis methods. The parameters calculated during an analysis of suitable unsteady equations are compared with the experimental data obtained in the 12-MW boiler of the Chalmers University of Technology in Sweden.

DESCRIPTION OF BOILER OPERATION

The 13.5-m-high boiler furnace is made of membrane-type waterwalls (Fig. 1). The waterwalls installed on the two opposite walls in the furnace lower part with a cross section of 1.4×1.4 m^2 and higher in the transport zone with a cross section of 1.4×1.7 m^2 are lined with refractory material. The cyclone with an inner diameter of 2 m is lined from inside with the same material. The heat-transfer surface in the transport zone has an area of 30 m^2. Particles from the cyclone enter into a lock composed of fluidized particles, from which they return into the furnace in bypass of an external cooler of particles, which was not used in these experiments (in firing biofuel). The boiler is fitted with a system for acquiring primary data that allows information to be received from several hundred measurement points. Sand with an average size of particles equal to 0.3 mm, which is used as bed inert material, is fluidized by primary air, and fluidizing air from the lock is also fed to the furnace. Secondary air is admitted into the furnace through nozzles placed at a height of 2.2 m from the air distribution grate.

The combustion products moved in the furnace with a velocity essentially higher than the terminal velocity of the majority of sand particles. This circumstance led to intense agitation of particles and strong circulation over the furnace–cyclone–lock–furnace loop. The experiments that had previously been carried out on that boiler showed the following.

(i) A fluidized bed with porosity $\varepsilon \approx 0.6$ exists in the furnace bottom part; its height $H_{\rm f.b}$ was maintained by supplying sand and was equal to 0.7 m.

(ii) A zone of splashes locates above the bottom layer, the average concentration of particles in which is equal to around 100 kg/m^3; the height of this zone reaches 1.0–1.5 m from the air distribution grate.

(iii) A transport zone locates above the zone of splashes; the average density of particles in this zone varies in the range 1–20 kg/m^3 and depends on the primary air velocity.

During operation on biomass at the nominal load (8 MW) and at 80% of the nominal load, the temperature at the furnace outlet is 20–30°C higher than that in the bottom layer. This means that, although fuel is supplied on the bottom layer surface, it burns not only in the bottom layer (in which semicoke combustion predominantly takes place), but also in the zone of splashes, in which the majority of volatiles burn out, but part of the heat releasing during this process is transferred downward into the bottom layer with the particles returning into it. Depending on the size of fuel particles and agitation conditions, part of fuel can also burn in the transport zone. The material returning into the furnace from the cyclone has a temperature lower than the temperature at the furnace outlet, because part of heat is transferred through the cyclone refractory insulation to water-cooled tubes, and another part of heat is spent for heating the fluidizing