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Opinion

Biomass Powder Clustering in Boilers/ Furnaces

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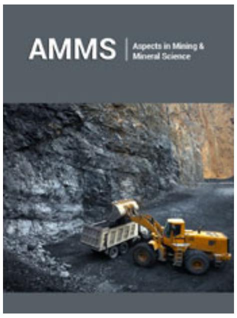

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Opinion

Biomass is an important future fuel, see for example [1-5], and in turn further studies are needed to investigate such fuel [6-9]. During combustion/burning, biomass powder clustering inside the boiler/furnace is an important issue, as the complete combustion of biomass fuel and its residual emissions depend heavily on the particle cloud and distribution [10-14]. Figure 1 shows photograph of biomass powder clustering before introduced into boilers/ furnaces. The aim of this study is to demonstrate the effect(s) of particle spatial distribution on biomass burning within boilers. Particle spatial distribution depends on a number of variables, such as particle size and shape. In particular, the biomass powder is prepared using logwood milling process and, as a result, the fuel powder is produced in irregular shapes and in various sizes [15-20]. When the particles exist in a variety of sizes and shapes due to the milling process, the clustering of the particles becomes unbalanced within the furnace/ boiler area, and that will effect on the particle combustion scenario, as discussed afterwards. Biomass powder clustering of small particles (micro or nanoscale) is more likely to follow the gas than larger particles; and therefore, it is more likely that smaller fuel particles will have a sufficient time in an oxygen-rich environment to ignite and achieve high flame temperature. As the suspension loses energy, the dissipation rate decreases significantly, and the particle cluster decreases [21]. Additionally, the energy in the suspension fuel decays over time as a result of viscous dissipation at the gas phase. One of the clustering effects, self-propelled particles may accumulate in a region of space where they travel at a reduced velocity [22]. Upon aggregation, the particles move more slowly in areas of high particle density due to steric obstruction. Such behavior can lead to the so-called motility induced phase separation [23]. Nevertheless, this step of separation can be prevented by chemically mediated inter-particle forces or hydrodynamic interactions. Such interaction could explain the creation of finite clusters in furnaces [24,25].

Figure 1: Photo of biomass powder clustering before introduced into boilers/ furnaces.

One reason of clustering may be due to inter-particle/particle/flow forces, as in the case of balance suspensions. Active forces would then resist this step of separation by dragging the particles in the cluster apart following two main processes. First, single particles can exist independently if their propulsion forces are sufficient to escape from the cluster. Second, because of the build-up of internal stress, a large cluster will split into smaller pieces: as more and more particles join the cluster; their propulsive forces add up until they break down their cohesion. Some studies of self-propelled particles show a strong tendency to accumulate and form clusters [26]. The exact mechanism leading to the emergence of clusters is not entirely elucidated and is a major field of research for many systems [27]. A number of different methods have been suggested, which could be useful in laboratory settings. Distribution of particles suspended in incompressible turbulent flows is studied by means of high-resolution direct numerical simulations. Particulate matter is shown to form fractal clusters in the dissipative range, with properties independent of the number of Reynolds. Conversely, in the inertial zone, the distribution of the particle is not a scale-invariant. Deviations from uniformity are dependent on the rescaled contraction rate rather than the local Stokes number. Particle distribution is characterized by voids covering all the scales of the turbulent flow; their hallmark on the coarse-grained distribution of the probability mass is the algebraic action at small densities.

In summary, some studies investigated biomass particle clustering. Dewei Qi [28] used a process known as Lattice-Boltzmann to test suspensions of both spherical and non-spherical particles under low Reynolds number flow conditions. Matuttis et al. [29] used the Discrete Element Method (DEM) to model particle tracing/motion in turbulent flow. Roberto [30] studied fluid/particle interactions and provided additional intensity effects on particle clustering. Lightstone & Raithby [31] proposed a new model for predicting the motion/tracing of particles in a turbulent flow at clustering conditions; the model takes into account interactions between particles and turbulent gaseous fluids. Mckay et al. [32] presented a simulation method using the Galileo number (Ga) as a function of particle size, particle density, fluid density and viscosity. In conclusions, the early studies reported that the particle clustering model varied in terms of particle shape and size, and clustering should be addressed carefully in the biomass particle combustions. Biomass clustering influences strongly on ash produced biomass combustion. Biomass ash causes a lot of operational issues during biomass processing, combustion and pollution. For example, biomass ash silicone is the main contributor to the wear of the blades of the size reduction unit. Potassium and calcium cause heat exchanger fouling and sluggishness in the bottom of the furnace. They include the shutdown of equipment on a regular basis, a decrease in the running time of the production units and also an increase in maintenance costs. The quantitative analysis of biomass ash content is therefore important for the design of the plant. Sometimes a pre-treatment leaching process is needed to remove ash from biomass prior to downstream processing. This helps to promote an effective and economical downstream process with high-quality output. The ash content of the oven-dried biomass was measured using the technique NREL/TP-510-42622. Biomass ashes are composed of Cl and S, with major elements (Al, Ca, Fe, K, Mg, Na, P, Ti, Si) and minor or trace elements (As, Ba, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Sb, Pb, Tl, V, Zn). Compared to coal, biomass usually shows higher amounts of Mn, K, P, Cl, Ca, Mg, Na, O and H, and lower amounts of ash, Al, C, Fe, N, S, Si, and Ti, respectively.

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