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2 Dimensional finite stochastic breakup model of biomass particle breakup

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HIGHLIGHTS

- ▶ We proposed a new model based on the anisotropy of biomass material in spatial structure.
- ▶ This model provides a proper description about the breakup of biomass material.
- ▶ This model could predict the change of biomass particles shape with the decrease of size.

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ABSTRACT

Due to the high content of cellulose, hemicellulose and lignin, the anisotropy of biomass particle in spatial structure induces the difference of mechanical properties in different directions. In this paper, based on the finite stochastic breakup model and anisotropy of biomass particles, 2-dimensional finite stochastic breakup model (2D-FSBM) of biomass particle was proposed, and the breakup process of biomass particle was investigated. In this model, the strength difference in different directions and the minimum mass ratio of a sub-particle to the parent particle were both considered. The simulation results agreed well with the experimental results in particle shapes, which indicated that 2D-FSBM could predict the breakup process of biomass particles.

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1. Introduction

Biomass feedstock destined for the conversion to fuel and other chemicals usually need to be ground to a certain particle size (Asadullah et al., 2002; Demirbas, 2005; McKendry, 2002; Rapagna et al., 1998). However, because of the distribution of cellulose, hemicellulose and lignin in biomass is anisotropic, particles with different mechanical properties are generated.

Kolmogorov (1941) proposed a stochastic theory for the breakup of solid particles that describe the cascade of uncorrelated breakage events. The breakup of solid particles was considered a random discrete process where the probability of breaking each parent particle into a given number of sub-particles was independent of the size of the parent particle. This theory was gradually applied to such processes as rock crushing and breakage of droplets. Based on Kolmogorov's theory, Cheng and Redner (1988) developed a scaling theory for linear fragmentation processes. Ben-Naim and Krapivsky (2000) investigated fragmentation processes with a steady input of fragments, solved for the full time-dependent behavior in terms of the input function, and found that the size distribution exhibits a universal scaling behavior in the long time limit. In addition, other researchers (Ernst and Szamel, 1993; Huang et al., 1996; Treat, 1997) described Kolmogorov's discrete stochastic process with mathematical models that were based on analytic solutions of the evolution of the kinetic equation. In these models, the particle size distribution evolves continuously with time instead of with the growing number of breakup events in discrete models. Apte et al. (2003) and Gorokhovski and Saveliev (2003) extended Kolmogorov's stochastic theory to the field of liquid spray. Zhou et al. (2000) proposed a stochastic breakup model for droplets and, based on Zhou's model, Gong et al. (2005) and Liu et al. (2006) developed the finite stochastic breakup model (FSBM).

However, these models are one-dimensional models, in which particles or droplets are considered as isotropic, hence breakup direction was not considered. In the present paper, a two-dimensional finite stochastic breakup model (2D-FSBM) is proposed based on the anisotropy in spatial structure of biomass particles to investigate the breakup process of biomass particles by a numerical simulation. The parameters of the model were confirmed with experiments.

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