A review of the effect of particle size and particle concentratyion on burning velocity calculation in FLACS-DustEx: a simplified approach

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Storage and handling of combustible dusts in many industries, e.g. metal ore processing, plastics and elastomers, pharmaceuticals, food and agricultural grains, involve a serious hazard of dust explosions. Powders and granular materials consist of distribution of particle sizes. In particle combustion problems, the particle size plays arguably the most important role in determining the relative contribution of chemical and transport processes. (Eckhoff, 2003; Ogle, 2016). This paper reviews the flame modelling and the effect of particle size and its concentration on burning velocity, with particular emphasis on numerical modelling of dust explosions in the process industries. In the computational fluid dynamics (CFD) tool FLACS-DustEx, the turbulent burning velocity is calculated using an empirical correlation that incorporates turbulent flow conditions and the laminar burning velocity. Building on a previous study (Ghaffari et al., 2018), this paper examines a new formulation for the laminar burning velocity that takes into account the effect of particle size and its concentrations with a new methodology, i.e. adapting Williams (1985) approach for liquid mist for dust flames. Particle concentration (loading) is also considered as an important factor in flame propagation. In case of lean mixtures of fuel particles, the particles will burn to completion while in case of rich fuels, some particles will be found in the combustion products with diameter smaller than the original diameter (Ogle, 2016). If a cloud of monodispersed particles is assumed, the laminar burning velocity of this heterogenous combustion can be estimated using the following expressions:

$$S_u = \left(\frac{\alpha_T \omega_{avg}}{\rho_u Y_{F,u}} \right)^{1/2} \tag{1}$$

where α_T is thermal diffusivity, $\rho_u Y_{F,u}$ is mass concentration of fuel (unburnt mixture) entering the flame, ω_{avg} is the average mass reaction rate, which is dependent on particle size,

$$\omega_{avg} = \pi d_p^2 \rho_s (-\chi_p) n_{p,0} \tag{2}$$

where ρ_s is solid particle density, density, $n_{p,0}$ is the initial number concentration of particles and χ_p is the rate of the particle diameter regression

Using the aforementioned simplified approach, a new formulation for the laminar burning velocity tailored for our large-scale simulation software will be derived.

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