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Non-spherical particle sub-models in comprehensive modelling of combustion systems

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Non-spherical particles are largely encountered in combustion flows, especially for the cases of biomass particles (e.g., coal-biomass cofiring in utility boilers). For instance pulverized straw particles are highly non-spherical and mainly flake-like, whereas pulverised wood is rod-like. In these cases the assumption of spherical particles in combustion models may lead to discrepant results under different aspects. The introduction of a shape factor enhances the surface area compared to that of a sphere, thus affecting not only the particle motion but also heating and surface reactions. The present work discusses some modelling critical issues related to the non-sphericity of solid fuel particles.

Firstly an accurate knowledge of size and shape distribution is needed. Existing data are scarce and not always quantitative. Particle size and shape distributions based on detailed characterization procedures should be applied to parent fuels and high heating rate chars to provide fundamental parameters for studying primary devolatilization and char oxidation, respectively (Biagini et al. 2009). Information on structural parameters (e.g., swelling, shrinking, fragmentation) can be obtained for non-spherical particles, also considering the anisotropic nature of biomass fuels (Kumar et al. 2006).

Secondly, commercial CFD codes allows generally to include the effect of non-sphericity on the particle motion by including a modification in the steady state drag coefficient (e.g. Haider and Levenspiel). The turbulence modulation may be important as pulverized biomass particles are generally bigger and more elongated than coal particles, thus they are likely to increase turbulence. So it is important to determine the effect of turbulence modulation on the efficiency of combustion. However there is a lack of validation of existing turbulence modulation models.

A further aspect is related to the particle heating. Generally the available models in commercial CFD codes are based on the spherical assumption, so that it would be necessary to develop some efficiency factor based on particle sphericity to correct the convective and radiative heat transfer (Mandø et al., 2010).

Due to different surface area available, elongated particles heat more rapidly than equal volume spherical particles. Biomass volatiles are thus released earlier with crucial implications on flame stability, oxygen consumption and eventually pollutant formation (e.g., NOx). Also the heterogeneous reactions with oxygen are generally based on the external surface area, so the proper description of the non-spherical particles is recommended to simulate the subsequent char oxidation step. Size reduction and fragmentation during this step need a specific approach to predict differences with respect to the case of spherical particles.

Finally the interactions between motion and combustion during all steps should be described to achieve a better understanding on biomass combustion.

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