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Experimental Study of the Behavior of Elongated Non-spherical Particles in Wall-Bounded Turbulent Flows

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Abstract : Transport phenomena and dispersion of non-spherical particle in turbulent flows are found everywhere in industrial application and processes. Powder handling, pollution control, pneumatic transport, particle separation are just some examples where the particle encountered are not only spherical. These types of multiphase flows are wall bounded and mostly highly turbulent. The particles found in these processes are rarely spherical but may have various shapes (e.g., fibers, and rods). Although research related to the behavior of regular non-spherical particles in turbulent flows has been carried out for many years, it is still necessary to refine models, especially near walls where the interaction fiber-wall changes completely its behavior. Imaging-based experimental studies on dispersed particle-laden flows have been applied for many decades for a detailed experimental analysis. These techniques have the advantages that they provide field information in two or three dimensions, but have a lower temporal resolution compared to point-wise techniques such as PDA (phase-Doppler anemometry) and derivations therefrom. The applied imaging techniques in dispersed two-phase flows are extensions from classical PIV (particle image velocimetry) and PTV (particle tracking velocimetry) and the main emphasis was simultaneous measurement of the velocity fields of both phases. In a similar way, such data should also provide adequate information for validating the proposed models. Available experimental studies on the behavior of non-spherical particles are uncommon and mostly based on planar light-sheet measurements. Especially for elongated non-spherical particles, however, three-dimensional measurements are needed to fully describe their motion and to provide sufficient information for validation of numerical computations. For further providing detailed experimental results allowing a validation of numerical calculations of non-spherical particle dispersion in turbulent flows, a water channel test facility was built around a horizontal closed water channel. Into this horizontal main flow, a small cross-jet laden with fiber-like particles was injected, which was also solely driven by gravity. The dispersion of the fibers was measured by applying imaging techniques based on a LED array for backlighting and high-speed cameras. For obtaining the fluid velocity fields, almost neutrally buoyant tracer was used. The discrimination between tracer and fibers was done based on image size which was also the basis to determine fiber orientation with respect to the inertial coordinate system. The synchronous measurement of fluid velocity and fiber properties also allow the collection of statistics of fiber orientation, velocity fields of tracer and fibers, the angular velocity of the fibers and the orientation between fiber and instantaneous relative velocity. Consequently, an experimental study the behavior of elongated non-spherical particles in wall bounded turbulent flows was achieved. The development of a comprehensive analysis was succeeded, especially near the wall region, where exists hydrodynamic wall interaction effects (e.g., collision or lubrication) and abrupt changes of particle rotational velocity. This allowed us to predict numerically afterwards the behavior of non-spherical particles within the frame of the Euler/Lagrange approach, where the particles are therein treated as “point-particles”.

Keywords : crossflow, non-spherical particles, particle tracking velocimetry, PIV
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