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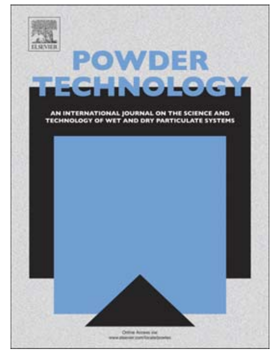

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3D Boundary Line Measurement of Irregular Particle with Digital Holography

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Abstract

The morphology of an irregular particle plays a key role in its interactions with the surroundings, and the 3D characterization of an irregular particle is of essential importance. Digital inline holography in Gabor configuration is applied to measure the 2D shadow texture and 3D position, as well as the 3D boundary line of irregular particles. The depth position of the 3D boundary line can be determined with a criterion of the local deviation of the directional gradient over a small tilted rectangle, which covers the interrogated boundary section. The method is firstly verified by rigorous simulated particle holograms and then by accurate experimental fiber hologram. The 3D boundary line of an irregular coal particle is also measured. Results show that the 3D boundary line of an irregular particle can be accurately retrieved from the reconstructed volumetric optical particle field. This capability of 3D boundary line measurement enables the application of digital inline holography to the 3D diagnostic of the morphology and dynamics of irregular objects, including 3D rotation.

Keywords: Digital holography; Irregular particle; 3D boundary line; Particle morphology

1. Introduction

The particulate is a common existing form of both natural and artificial materials, and is widely encountered in both daily activities and scientific and industrial processes. A non-exhaustive list of examples includes food powders, soil and sand, drops and solid fuel particles [1]. Studies of particles and their interactions with the surroundings have attracted attention for millennia. Apart from regular particles, such as spheres, cubes and so on, which can be described by simple analytic parameters and are consequently widely used in numerical investigations of particle systems [2], irregular particles have a complicated 2D image texture or even a 3D surface, which can be mathematically expressed as a 2D Fourier series or a 3D spherical harmonic series respectively [3]. In order to characterize the geometrical properties of irregular particles, several descriptors have been proposed. Based on the dimensions of the associated variables and methods, those descriptors can be classified into 1D "*form*", 2D "*shape*", and 3D "*surface*" descriptors [4, 5, 6, 7, 8]. The term "*form*" is usually used for the 1D parameters, i.e. length, width and thickness [4, 6], and the 2D "*shape*" usually refers to the characterization of the particle projection image, i.e. roundness and area, and consequently, "*surface*" is related to the real 3D geometrical properties which are beyond the descriptions offered by both 1D "*form*" and 2D "*shape*", such as volume and sphericity. In recent decades, several optical techniques have been developed to measure those geometrical properties. The laser diffraction based methods and devices have been widely used to measure the particle size distribution [9]. Phase Doppler anemometry (PDA) [10] can measure the size as well as the translational motion of transparent spheres inside a small control volume. Interferometric laser imaging for droplet sizing (ILIDS) has been extended to measure the size, as well as the 3D position, of transparent, spherical particles[11], and even to characterize the 2D dimensions of irregular particles [12]. Direct imaging with a lens or an objective is a common approach that has been extensively employed for the characterization of 2D morphology of irregular particles with image analysis [13]. To gain a deeper understanding of an irregular particle, it is of interest to measure the real 3D surface, and three dimensional laser scanner (LS) [14] and computed tomography (CT) have been introduced as experimental solutions to achieve this. The laser scanner (LS) technique scans the exterior surface