Imagerie interférométrique de particules irrégulières pour l'étude d'écoulements:développement d'un dispositif adaptatif et de méthodes d'analyse par apprentissage profond.

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Abstract

Out-of-focus interferometric particle imaging (IPI) is an optical particle sizing technique used to determine the shape and size of micrometric particles: 20 µm − 2,000 µm. They can be of different natures, for example, ice crystals suspended in the atmosphere, volcanic ash, clouds of sand grains or coal particles scattered around thermal power plants. The previous examples all have one thing in common, they are rough particles, with irregular shapes and the results of this thesis work are based on these characteristics. Image acquisition with this technique is based on a simple operating principle. A rough particle is illuminated with a laser; it diffuses part of the incident radiation in all directions due to the asperities on its surface. These asperities create secondary sources of the incident radiation. An out-of-focus imaging system records interference images from these secondary sources. The development and improvement of programs to reconstruct the shape of the particle from its interferometric image is carried out with an experimental bench equipped with a micro-mirror matrix (DMD). The particle is "programmed" on the DMD. The micro-mirrors that simulate the secondary sources of the particle reflect part of the incident beam towards the imaging system. This thesis work focuses on the one hand on the creation of a neural network to classify the shape of a particle from its interferometric image. This neural network has shown recognition in 100% of cases. On the other hand, the development of another neural network to reconstruct the envelope of irregular particles from their experimental images has shown very good reconstruction quality between the programmed shapes and the reconstructed shapes. In both cases, databases consisting of several thousand experimental images were acquired with an experimental setup equipped with a micro-mirror matrix to "simulate" rough particles. In addition, within the framework of this technique, two additional works were carried out: (i) first a first method of correction of spherical aberration, by passage from the Cartesian basis to the polar basis, and a second of simulation of spherical aberration in IPI, by decomposition of the phase term into Gaussian functions; and (ii) the realization of an adaptive interferometric imaging system based on a liquid lens was developed to reduce the overlap of interferograms by instantaneous adjustment of the defocus of the imaging system