Localized fluidization in a granular medium: boiling cavity and chimney of fluidization

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ABSTRACT

In the industry, several processes can initiate localized fluidization in a granular material as the so-called spouted beds [1], used to mix a granular medium by an upward flow, or the fluidizer systems used for the maintenance of navigable waterways [2]. Natural situations of localized fluidization are observed in some geological "fluid-escape" structures [3] or in levees where "sandboils" are likely to appear during a flood and, potentially, to initiate backward erosion along the bottom of the levee [4].

The general situation observed here corresponds to a localized upward water flow through an immersed granular medium. There are only few studies on this topic dealing with punctual [5] or homogeneous [6]. Above a given threshold, a localized instability develops along a fluidized chimney.

Here, the development of the fluidized pipe is probed locally thanks to a matching-index technique: the granular medium is made of spherical borosilicate glass beads whose refractive index is matched to the one of the liquid which is no more water but a mixture of mineral oils. A small amount of fluorescent dye is added to the oil so that only the liquid phase reemits light when illuminated by a laser sheet and the grains are made visible by contrast. The grains are filled in a rectangular cell supplied at the bottom by an upward liquid flow at constant flow rate through a small orifice. At a small flow rate, the bed remains static; at an intermediate flow rate, a boiling cavity appears in the vicinity of the injection hole and eventually expands up to the top of the medium. At a bit larger flow rate, the whole height of the granular layer gets fluidized in a vertical chimney. A detailed study of the phenomenon is presented here: threshold of cavity formation, regime of stable boiling cavities, dynamics of cavity fluidization front, regime of fluidized chimney, hysteresis behaviour. The interaction between two or three distinct upward flows is also investigated and analyzed.

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