Transient regime to fluidized chimney within a granular bed by means of a 2D DEM/LBM modeling

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ABSTRACT

A fluidized state within a granular bed is reached when the upward force exerted by the flow can balance the buoyant weight of the particles. This may also occur in a localized manner when the fluidization is induced by a small fluid injection at the bottom of a grain pack. Many industrial processes rely on such liquid-solid fluidized beds, often showing cases of localized fluidization (spouted beds). In the context of dike safety, a seepage flow through the foundation of an embankment is susceptible to generate such a local fluidization, called “sandboil”, and possibly initiate a piping process by backward erosion, one of the four general processes reported for internal erosion [1]. Several previous studies have addressed specifically this question and analysed the formation of a vertical chimney of fluidized soil, either through experiments [2, 3] or numerical simulations coupling Discrete Element Method (DEM) and Lattice Boltzmann Method (LBM) [4]. However, most efforts have been concentrated on the steady fluidized chimney while little is yet known about the transitory development of fluidization before reaching this final chimney [3].

In the present study, a systematic analysis of the transient regime to fluidized chimney is carried out by means of numerical simulations based on a 2D DEM/LBM modelling. The results reveal that a critical fluid velocity U_c can be defined fairly precisely from the divergence of the duration of the transient regime T_0. Then the critical velocity U_c was evaluated in a systematical and consistent way for ten different parameter sets by changing either grain properties (density, diameter) or fluid properties (viscosity, density), or reducing the acceleration of gravity by a factor of ten. A scaling law can be proposed for U_c as a function of grain diameter, fluid viscosity and reduced gravity. Introducing the relevant dimensionless numbers of the problem, namely Reynolds number Re and Archimedes number Ar, this law is simply equivalent to $Re_c \propto Ar^{3/4}$ where Re_c incorporates the critical velocity U_c. Moreover, by defining an expansion rate $V_0=T_0/H_0$, and a related Reynolds number Re_0, it is finally demonstrated that not only the critical velocity but also the whole transient kinetics can be accounted for by a general relation that reads: $Re_0 /Re_c \propto (Re/Re_c -1)^{3/5}$.

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