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Motion of grains in a vibrated U-tube

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Abstract We investigate experimentally the behavior of the rate of growth of a column of grains, in a partially filled vertically shaken U-tube. For the set of frequencies used we identify three qualitatively different behaviors for the growth rate γ as a function of the dimensionless acceleration Γ: 1) an interval of zero growth for low Γ with a smooth change to nonzero growth, analogous to a continuous phase transition; 2) a sigmoidal region for γ at intermediate values of the dimensionless acceleration Γ; and 3) an abrupt change from high values of γ to zero growth at high values of Γ, similar to a first order phase transition. We obtain that our data is well described by a simple differential equation for the change of the growth rate with the dimensionless acceleration of the vertical vibrations.

Keywords Granular material · U-tube · Vertical vibration · Transport · Instability.

1 Introduction

The collective rise of grains in one branch of a vertically vibrated U-tube and some related instabilities like heaping and granular transport in vibrated granular deep beds in partitioned containers has been the subject of research for decades [1,2,3,4,5,7,8,9]. In this work we concentrate in the experimental characterization of the rate of growth of the rising column of grains in a partially filled U-tube for different frequencies. The mechanism responsible for this interesting behavior is still an open issue.

In a previous work [5] the behavior of a vertically vibrated granular system in a partially filled U-tube at low frequency was studied. A collective granular transport upward through one of the branches of the tube was observed for small grains. The experimental results were compared with a model based on the idea of cyclic fluidization [6]. In that model it was assumed that for low frequencies and sufficiently high amplitudes of oscillations the granular bed fluidizes cyclically in such a way that an effective upward acceleration acts on the grains while these are in a fluidized state. Consequently, an instability appears and the free surface of the bed on either branch of the U-tube rises while the other goes down. Therefore, one of the branches of the tube is rapidly filled and simultaneously the other empties. That model captures some relevant aspects of the observed behavior for low frequencies, as for example the exponential growth of the granular column and the monotonic increase of the growth rate with the dimensionless acceleration of the vibration; however, we have found some important quantitative discrepancies. The above model for the measured growth rate γ versus the maximum dimensionless acceleration Γ of the container provides only a crude approximation for low frequencies. As the frequency is increased above $10\,Hz$, it becomes clear that the model is insufficient to describe this phenomenon.

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