Bifurcations in vertically oscillated granular layer

and the characteristics of solid-fluid transition

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ABSTRACT

Vibrating granular layer in a confined vessel shows a variety of patterns like *undulations* and *ripples*. The former are characterized by arch-like deformation of the layer with integer or half-integer number of waves along the layer, and are typically observed in a thinner layer with smaller acceleration of external forcing. Here, the horizontally dilated layer due to the impact on the container bottom wall, is forced to undulate so as to adjust the elongated length of the layer, reminiscent of the buckling and bending of an *elastic* plate. This type motion can be generated when the layer number (layer thickness divided by grain diameter) exceeds three, because the middle layer needs be vertically squeezed and dilated horizontally[1][2]. On the other hand, the ripples, which are generated by larger amplitude of accelerations, are characterized by crests and valleys alternating with a period two or four of the external forcing. In a *thinner layer*, the whole material is *fluidized*, and its behavior is similar to the one observed in parametrically excited fluid except the periodic appearance of clear space between the layer bottom and the container wall. In contrast to the ripples in a thinner layer, particles are almost immobilized in the lower part of the *thicker layer*, so that only the upper part of the layer is fluidized and develops into ripples. Thus only the upper fluid-like part of the layer, and not the total layer thickness, is relevant to the dispersion relation. A closer look of the latter reveals that both elastic and fluid-like regions coexist in the thicker granular layer, and the boundary of both phases propagates in the granular material[3][4].

In this paper, we shall focus on the first bifurcation from a flat to an undulating granular layer, and the second one that is associated with solid-fluid transitions. Experimental evidences on the onset of these regimes and their hystereses observed at increasing/decreasing magnitude of external oscillation, characteristics of the constituent particle motions, as well as the density wave propagation, are shown. A simple model that describes the latter and pattern mode selection is proposed.

REFERENCES

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