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Short Communication

Comment on: “Convective flow of granular masses under vertical vibrations”

(C. Laroche, S. Douady and S. Fauve, *J. Phys. France* 50 (1989) 699-706)

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Résumé. — Nous montrons que le rôle de l'air doit être négligeable dans les expériences de Laroche *et al.* Nous nous appuyons essentiellement sur les expériences de Faraday qui expliquent les figures de Chladni et sur les interprétations qu'il en donne. Nous invoquons aussi d'autres résultats plus récents.

Abstract. — It is demonstrated using Faraday experimental results and interpretations that air should not play a major cast in the experimental data published by Laroche *et al.*. This is also supported by other more recent studies.

The experimental results reported in this paper are really beautiful and no doubt they will help understanding the convective flow regim and the very peculiar shapes and geometries that a sand pile can take when it is vertically shaken. However, it seems to us that the interpretation given in this paper emphasizes the effect of air too much, so that these phenomena are still misunderstood from our point of view.

Furthermore, one can test qualitatively and quantitatively a correct interpretation of these results, when it will be achieved, by comparing directly its theoretical predictions to the other data already published [1 – 6]. Such a global interpretation is not yet possible: the published experimental behaviors are quite different from one another, although they have been obtained using slightly different experimental set-ups [1 – 6]; this tends to prove that a vibrated sand pile is sensitive to small perturbations, such as a change in the boundary conditions [7] or a small transverse vibration [7]. In [7], we have not only tried to discuss such possibilities in a general fashion, but also to check the relevance of already existing theories [2 – 3] to interpret these phenomena [1 – 6]. We want to discuss here only the relevance of an existing air flow, which is claimed by Laroche *et al.* to create the convective pattern. We do not deny the existence of this air flow, but only contest that it is the motor of the pattern under these experimental conditions, (which are not too

large accelerations and large grains): for us, the air flow is only a result and not a cause of what is occurring.

In order to prove this point, let us first recall a few conclusions of Faraday's paper: when spreading a light powder (lycopodium, for instance) on a vibrating plate, he has obtained heaps located at anti-nodes of vibrations (places of largest vibrations, i.e. nodes of pressure); but when spreading sand on the same plate, he has got heaps at nodes of vibrations and has concluded to the lack of air effect in this case; its interpretation was that the speed of the Brownian motion of grains was smaller at the nodes so that there were accumulations of grains at these points and formation of heaps. On the contrary, for light powders, the effect of air was important and especially of an air flow induced by the plate vibration and located near the plate; in order to strengthen this point, he has stuck small pieces of paper on the plate and used them as air deflectors, so that he has changed the geometries and locations of light-powder heaps, (point 27-32 of Faraday's paper [2]); (but he does not mention any change in the geometry of sand heaps using this procedure). So he has concluded to the existence of two different motors of heap creation, one is induced by a direct action of the mechanical vibrations of the plate on the grains and the other one is related to the air flow generated by the plate vibration, (which can carry grains only when they are light enough of course); the latter process is thus only important when the powder is light (i.e. made up of very small grains). He has confirmed this analysis by exhausting the air from the container surrounding the vibrating plate, (point 33-36 of his paper): below a 5 cm mercury pressure, he has got light-powder heaps located at nodes of vibrations, as if it were a large-grain powder; but above 10 cm mercury pressure, light-powder heaps are recovering their classical locations, at anti-nodes of vibration, so that the atmospheric-pressure patterns are recovered.

Futhermore, other papers support this point of view of Faraday: they claim [3, 8] that air has only little influence on the dynamics of a vibrated bed when the size of its grains is large enough, which is the case for grains in the experiments of Laroche *et al.* (0.63 to 0.80 mm diameter).

Concerning our own experience of granular materials, we do agree with this approximation and we think that air effect might be neglected: during our experimental investigation of the properties of a vertically-shaken sand pile [5 – 7], (using glass spheres of diameters 0.2 mm or 0.4 mm or 1 mm), we have checked the possible existence of an air effect in two different ways and proved that air was negligible. Firstly, we have repeated our experiments at different air pressures, from 4 mm of mercury to atmospheric pressure, and we have not detected any change of the heap shape or of the convective-flow pattern (we want to emphasize that 4 mm of mercury is 10 times lower than the lowest pressure studied by Faraday and at which he had changed the locations of lycopodium heaps). Secondly, we have investigated the shape taken by the heap when the boundary conditions are changed; for instance, we have covered the walls of our closed cell, which contains the granular medium, with a metallic grid located at a given distance from the wall so that the air could have flown freely from the bottom to the top of the pile without passing through this pile; (grids were permeable to air but not to the beads); we have detected no change of the pile characteristics when it was vertically shaken under these circumstances.

However, we have already mentioned the great sensitivity of the experimental behaviors obtained with vibrated sand pile on the experimental conditions such as boundaries. So, as Laroche *et al.* have not used the same set-up as ours, a small doubt might persist and it would be better to test directly the influence of the air in their case by using a grid instead of a plate in their experimental set-up. (Such an experiment has also been used by Savage [3] to test the negligible importance of air).

The strongest argument of Laroche *et al.* which supports the air influence is the absence of convective pattern when vacuum (10^{-5} Torr) is performed in their cell; however, it might occur that spheres get spontaneously charged at such a low pressure so that the medium becomes strongly cohesive; such electrostatic charges can already occur in dry air as mentioned by Savage [3].

As a last remark, we have restricted the discussion to the influence of an air flow on the pattern obtained by Laroche *et al.*, and said that it is of little importance. We have not yet discussed the effect of a quasistatic surrounding compressible and viscous fluid on this pile; this may be more important than it can be thought at first sight, since this surrounding medium ensures sound propagation even in a non-cohesive and unpressed granular medium, i.e. when it is levitating. It also ensures a time dependent resistance to deformation under the same conditions (levitation).

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