PAPER REF: 4733

NEW VIBRODYNAMIC PHENOMENA RELATIVE TO THE SPECIFIC VOLUME FORMS OF LOOSE/GRANULAR MATTER

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ABSTRACT

New effects concerning to the movement of sandpile and any bounded part of sand layer (i.e. "quasi-plane" sandpile) on inclined vibrating base plate are presented and discussed. In some small region of vibrating parameters the mentioned movements are characterized by small friction between the bottom of moving sand volume form and the surface of base oscillating plate and also by big stability of form of these sand structures.
Keywords: sandpile, quasi-plane sandpile, vibromovement with small friction, inclined vibrating base plate.

INTRODUCTION

Granular media seem in the worldly consciousness as "ordinary, unremarkable" objects because of its ubiquity as nature and building materials. In contrast, such media are objects of intensive scientific attention and researching with ongoing identification of new problems and new effects. The whole history of regular research of granular media can be divided into two successive stages: up to 80th of the last century there were practical applications therefore the requests of applied nature lied at the heart of the almost of all researches about these objects (Sokolovski, 1965, Klein, 1977) and after the indicated above time border, when the granular media (first of all, its dynamics) is the subject of numerous fundamental researches in physics, acoustics, mechanics, mathematics, etc. In above designated time of the joining of "communion" problems of granular media with basic sciences the authoritative physical journal "Physical Review, ser. E" has inputted a special section about granular media problems into contents of this journal. Also in this "new" historical period the large number of studies and publications devoted (and devote now) to the research of spatial structures formation and their interchangeability on the surface of the vibrating layer of granular material (Aranson, Tsimring, 2006), which is clearly not a direct "access to the practice", and probably relates to the theory of self-organizing structures (compare with the patterns in the Belousov-Zhabotinsky reaction). The investigation of behavior (dynamics) of granular media under vibration exposure gives an opportunity to observe and study various transitions (such as phase and aggregative) and structuring processes, which are characteristic for granular media in vibrating fields (Eshuis, 2007). One of the features of a vibration as phenomenon is the varied manifestations of this effect and its purposeful applications: vibrations in the natural and anthropogenic processes, vibrations are inherent in man-made mechanisms, vibrational spectroscopy of materials and vibration testing of constructions, vibrational medicine and many others. But it is frequently forgotten that vibration action is the irreplaceable condition for the carrying out of any experiments under liquid and granular media; this allow to observe specific vibrodynamic effects on the surface or inside bulk of the liquid/granular layer. It is interesting that the vibration action on granular matter is equivalent of the heating and vibrated granular matter is characterized by corresponding temperature. Though the specificity of utilization of vibration as action factor in experiments (as experimental "tool"), this aspect of concerned physical phenomenon has distant past history; perhaps the first scientific publications about these experimental "modus operandi" – vibration and about the specific effects induced by vibration in granular/liquid matter (on the surface of layer of these media) were appeared two famous Faraday's articles (Faraday, 1831a, 1831b). The last two-three decades of present time period original Faraday's experiments attracted new attention and they developed for obtaining of new experimental results. It seems that the possibilities of these (and analogous) experiments are exhausted. But new results could be obtained under any changes in traditional procedure of experiments and under vibroactions on new objects (new granular volume forms).

This article represents the research of vibrated granular matter taking into account the above-said concepts. Number of the new fixed effects will be presented, which are manifested in experiments on vibrating granular medium in the form of dry sifted sand with a typical particle size of not more than 0.25 mm, and 90% were in the range 0.1 - 0.2 mm. All the experiments were conducted with relatively small amounts of sand placed on the square bottom with sides 120 mm of a Plexiglas vessel, and bottom of the vessel was strongly connected with a movable table of a compact shaker PVKU - 1 (portable vibrocalibrating device). Vertical acceleration and amplitude of the vibrating table with the vessel measured by vibrometer of the type 2511 from "Brüel & Kjær" (see Fig. 1a).

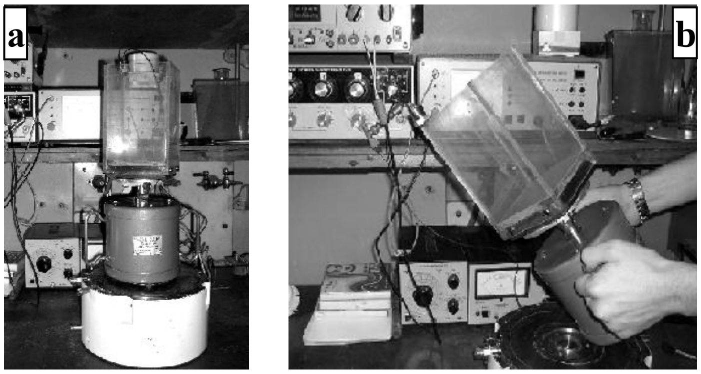

Fig.1 (a) – shaker is in a stationary vertical position on the stand, (b) - management of shaker's position (including slope) via retention by arms.

PROCEDUES AND OBJECTS FOR THE DISCLOSURE OF NEW VIBROEFFECTS

Despite the simplicity of the technical basis for the carried out and demonstrated here experiments there are some features for them realization that been never used by other researchers; this gave entirely new nature and led to the finding of new effects.

First of all, because of small size of shaker (see Fig. 1a) and light weight (the weight with attached vessel and with some sand in it isn't more than 4 kg), the majority of experiments was carried with regime, when the shaker was in hands for the possibility to find in the "manual management" an optimal angle of inclination of the construction (see Fig. 1b) to obtain the desired effect.

With regard to the numerous experiments with vibrating granular (bulk) media by other researchers it must be said that all they worked (and work in present time) with fixed heavy vibrating installations, often supplemented by other complex structures (e.g., special lighting, high-speed photography equipment, etc.). Of course, all this apparatus gives more correct measured data, recorded in detail the processes, but doesn't provide the "freedom" in choosing the right positions and modes of vibrating action on the granular (sand) forms and limits the possibility of "capture" of the interesting effects. The arms (and the vibrator in arms) are the most effective control and responsive corrective system for search and examination of such "subtle" vibroeffects.

Also, whereas the situation in applied research of interaction of granular media with a vibrating inclined plane reflects the principle of operation of really existing mechanisms and wherefore the investigations with such systems are usual, inversily in basic researches there are only a few works (for example, Aerov AA, et.al. 2001) with searching and studying of granular media behavior on inclined vibrating base. Therefore, our further efforts are focused on such systems (Fig. 1b).

The third innovation relates to granular object of vibroaction: traditionally this is a layer of granular/loose matter that "clamped" between side walls and specific set of effects is proper for this granular form; the presented experiments were conducted with area localized portion of sand (quasiflat sandpile), which can move over vibrating base plate (see Fig.2). For such form were obtained new effects connected with vibromotion of sand portion onto inclined vibrating base plate.

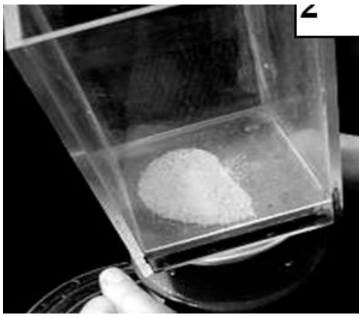

Fig.2 Quasiflat sandpile

RESULTS AND CONCLUSIONS

As the first demonstrated hear results were be the found effects connected with the features of movement of the special but simple geometrical sand formation named as "sand puddle" (or "quasiflat sandpile") on an inclined vibrating surface. Under the "sand puddle" (or "quasiflat sandpile") is meant the limited in area and relatively thin (~ 1.5 - 2 mm in the central part) layer of dry sand (see Fig. 2). This is hand-made object because his shape doesn't form during the pouring of sand. This object had fallen out focus of researchers interested by vibroactions on granular matter or sand.

"Starting point" for representing here effect is show in the top two frames ((1) and (2)) in Figure 3 results of the slope of the base with "sandy puddle" in the absence of vibration. It is important to note that in these conditions and for appropriate microstructural characteristics of the vessel bottom and the individual granules the sand puddle as whole attaches to bottom of the vessel during its inclination in a wide range (from 0 to ~ 43 degrees) and the form and shape of puddle do not change (see Fig. 3(1)) in this range (before the critical angle of inclination φ_{cr} = 42°). However, once the angle exceeds the value φ_{cr}, well-known phenomenon, called an avalanche, (landslide, etc.,) occurs, when the surface layers of the "puddle" move out ahead of it and form a characteristic "tongues" (see Fig. 3 (2)). Passing, we note that so far the theory of this phenomenon is not fully developed.

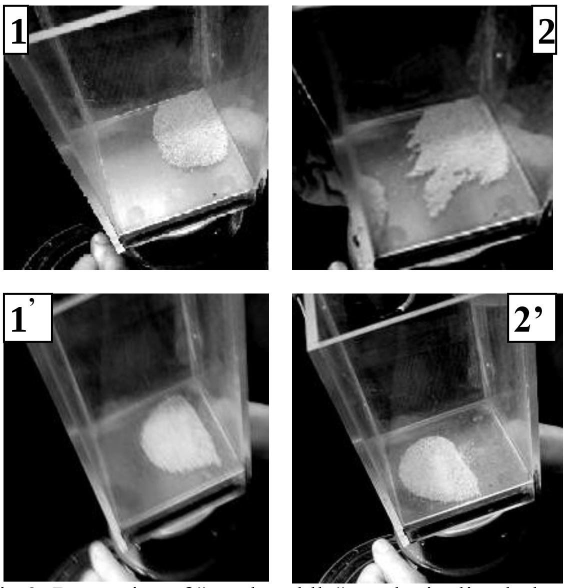

Fig.3. Dynamics of "sand puddle" on the inclined plane: top row - without vibration (when tilted ground "puddle" is not shifted, and its upper at ~ 42° form an avalanche) at the bottom – free movement of "puddle" on the vibrating inclined plane with preservation of the form.

In the presence of vibration it succeeded to capture the effect wasn't noticed before, when in a rather narrow range of vibration parameters (frequency from 16 to 18 Hz, amplitude A, respectively from 1.4 to 0.9 mm), "sand puddle", located at the bottom of the vibrating container, wasn't changed in its shape but moved freely (without experiencing significant sliding friction) on the sloping bottom, and readily responded to the changing orientation of the slope (see Fig. 3 (1'), (2')).Most clearly the effect of "sliding" of structure of sand on an inclined vibrating substrate is shown at angles φ in the range of 22 to 27 degrees. This effect is determined by the vibration, and remarkably two factors are joined together:
1) a good consolidation of the structure of individual particles of non-adhesion dry sand (effect of packing); original form of sand puddle remains virtually unchanged during the motion of this structure as a whole, 2) significantly reduced value of the coefficient of slip friction between the base of the whole sand structure and vibrating substrate (in this case, the vibrating substrate made of Plexiglas). The manifestation of these two factors is clearly captured by comparison shots of the lower and upper row shown in Figure 3 (to save space, each number is represented by only two frames corresponding to almost the beginning and end of the process, in fact, comparison of a series of frames, obtained at shorter time intervals, exists).

To explain this effect, for first we note that one of the main parameters that characterize any process associated with the vibration, is, namely, the dimensionless (with respect to gravity) acceleration $\Gamma = A\omega^2\cos(\varphi)/g$ (A - the amplitude of the displacement of the vibrating with the acceleration of a substrate a, ω - angular frequency of vibration of the substrate, g - acceleration due to gravity, the cosine factor is present because of the vibrational displacement of the substrate in the direction of its normal, which, in turn, is inclined to the vertical direction by an angle φ (see Fig. 4)). In the scientific literature, the parameter Γ is also called the rate of acceleration. According to the above values of the frequency and amplitude of substrate vibration, as well as the angles at which the observed effect is described, it realized for the values of the Γ slightly exceeding unity. It is known (see, e.g., An, at.al., 2008) that is actively developed in recent years - studies of the effect of vibration exposure on the degree of compaction ("packing") granules (particles) in an array of granular media showed the best result (up-attainment of the maximum packaging effect) are in the vibration exposure corresponded to low (from one to two) values of Γ. Note that the increase in the intensity of vibration on the contrary incompact granular mass, bringing it into a state of vibrofluidization, vibroboiling, etc. Thus, as the basis of the observed effect, we have a maximum compaction of the prepared "sand puddle" with the "best" package of individual grains of sand in it when the chosen vibration conditions are. We can say that in determining the general theory of granular media filled up the mass of the static state as a solid state, in our experiment, the selected mode of vibration exposure increased the degree of "solidity" studied flat structure, which was manifested in its consolidation and the immutability of the form when have moved. At the heart of the distinctive features of the second effect lies a reducing the slide friction of flat sand structure when moving along an inclined vibrating plane - there are two interrelated reasons based on the first effect, i.e. consolidation.

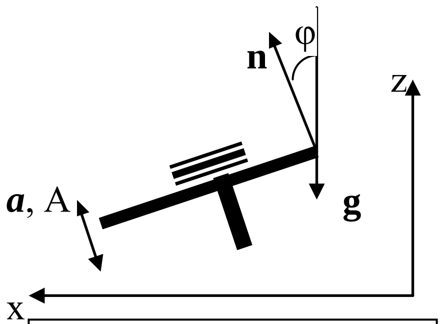

Fig. 4. The geometry of the inclined vibrating substrate (vibrating table)

Indeed, since in general the whole effect is observed for values of Γ somewhat higher than unity when projected to the axis z, then in a few brief intervals of the period of vibration, the flat structure of the consolidated sand will fall from the plane of the base, falling straight down, and then gradually shifting along the plane base to its "bottom" edge, and this process of moving due to falling through the air it is not connected with the action of sliding friction of sand along the plane (see Fig. 4).

Also another remarkable new effect observed in the experiment is performed. On the first view it is similar to the previous one, but has different mechanisms. The main object of this effect is a sand pile on the vibrating vertically plane (bottom).

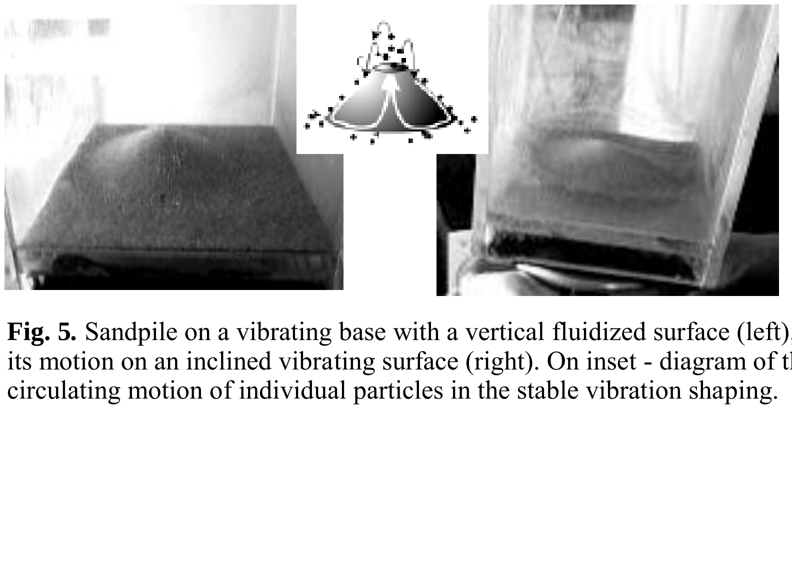

Fig. 5. Sandpile on a vibrating base with a vertical fluidized surface (left); its motion on an inclined vibrating surface (right). On inset - diagram of the circulating motion of individual particles in the stable vibration shaping.

Appearing the analogue of a well-known usual conical heap formed by the precipitation of a granular medium on a flat surface, sand pile on a vibrating base is a more complicate object concerning its structure since all formed particles (grains) are in continued circulating motion (see inset in Fig. 5). Full lateral surface erupts a dense stream (maximum - from the top) of individual particles (grains), demonstrating its fluidized state. Shown in Fig. 5 photos were obtained at a frequency of vibration - 21 Hz, the amplitude of the vibration - 1.7 mm, so the intensity of vibration Γ was in the vertical motion of the vibrating table a little more than 3 (at an inclination of the vibrator, this value will be slightly less). The experiment shows that a significant cause of the above-described behavior of particles in a vibrating motion is the air near heap side, under its base and inside the heap; the direction of air motion is shown by white arrows in the inset of Fig.5. All these features, in general, also give the effect of "easy" sand pile moving on an inclined vibrating surface (see the right picture in Fig. 5). The circumscribed air movement plays the role of air cushion for conical sandpile motion on inclined plane with much reduced friction between sandpile bottom and vibrating base plate.

ACKNOWLEDGMENTS

This work was supported by grant RFBR (11-02-01208) and a grant from the Government of the Russian Federation for state support of research conducted under the supervision of leading scientists at Russian institutions of higher education № 11.G34.31.0066.

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