Journal of Engineering Physics and Thermophysics, Vol. 73, No. 5, 2000

ENERGY-DYNAMIC MODIFICATION OF THE INHOMOGENEOUS SURFACE OF LOOSE BODIES UNDER THE EFFECT OF SEISMICS

I. N. Aliev, O. V. Gur'yanova, and G. V. Podguzov

UDC 550.344.4

Energy and dynamic models which explain the effect of rejection of a foreign structure from a loose medium are suggested. The corresponding evaluations show that forces which can expel the body to the surface appear in a fast seismic field.

1. The description of a loose inhomogeneous medium – powders, grounds, etc. – is an extremely complex problem. To date there has been no sufficiently adequate approach to modeling these media. The contemporary theory of multiphase (heterogeneous) systems bypasses this object of investigation (see, e.g., [1]). It is clear that neither the methods of continua (hydromechanics) nor the mechanics of solids can be used here. Thus, for example, the introduction of the averaged density of the medium that consists of a dense or nearly dense packing of spherical different-radius particles and the assumption of certain phenomenological dynamic characteristics (for example, an analog of viscosity) will take such important phenomena as friability or restructurization under the effect of external factors out of consideration. The latter is the object of discussion in the present paper. Such a medium requires quite a new approach. However, certain partial problems can be explained and evaluated by the general principles of mechanics. The medium considered can be modeled as follows. The object of investigation consists of different-size spheres (with a varying degree of packing density); in nature this can be loose ground with foreign inclusions which differ from the basic medium in both their properties (in particular, density) and size or shape. The behavior of this medium is of extreme interest – it is enough to recall a well-known fact that the earth "rejects" structurally different inclusions as if expelling them to the surface (the effect of a "potato sack" when after numerous shakings larger tubers appear at the top). To these issues relate problems of detecting various munitions (mines) and shells in the ground, especially sandy ground. It should be noted that within the framework of the suggested model, all the effects have a surface character. It is well known that as a result of various processes (both purely mechanical and physicochemical), structural changes, which lead to specific surface phenomena, appear on the surface of the medium. The problem of surface restructurization under the effect of elastic waves is of extreme practical interest. In particular, realization of various instabilities is possible. However, the overwhelming majority of papers published on this subject deal with the surfaces of a continuous medium (a solid or a liquid) (see, e.g., [2]).

2. To solve this problem, we use an energy approach – we apply the method of minimization of the potential energy of the system. In the present section, we will approximate the structure by a set of a large number of different-size spheres. It is clear that if all the spheres have the same radius, then any mixing of them does not change the potential energy of the system. We note an important fact – consideration is carried out for a dense packing of spheres. It is known that there exist two types of dense packings: hexagonal and cubic, and also hybrid combinations in which transition from one dense packing to the other occurs. It is remarkable that in all these structures each sphere touches twelve neighboring spheres and the density of packing (ratio of the volume occupied by the sphere to the volume of the entire space) is $\pi/\sqrt{18} \approx 0.74$. Accordingly, the mean density does not depend on the radii of the spheres. Therefore, the structure consisting of spheres of

N. É. Bauman Moscow State Technical University, Moscow, Russia. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 73, No. 5, pp. 961-963, September–October, 2000. Original article submitted June 3, 1999; revision submitted December 16, 1999.

 1062-0125/00/7305-0942$25.00

the same radius is of no interest to us. If there exists a certain number of types of spheres, with a large number of spheres of each type, then the problem is modeled by a horizontally layered (stratified) structure; within each layer the density is the same, $\rho = \rho_0\pi/\sqrt{18}$, where ρ_0 is the density of the material of the spheres, and reversal of the place of the layers also does not change the potential energy of the system. Of principal interest is the structure modeled by a large number of spheres of one size and inclusions (single or very rare) of spheres of a much larger size ($R_2 \sim 10\text{–}100\, R_1$). Since the region adjacent to a large sphere is disordered and has a density smaller than the density of a dense packing, the potential energy of the system decreases as this region moves upward. This is the manner in which the restructurization with the expelling of large fragments to the surface occurs. A real object – the grounds of the earth – is subject to constant seismic shakings. In this case, "reshaking" of the structure takes place, and larger-scale fragments can be expelled upward, thus reducing the total potential energy. It seems likely that the "potato-sack effect" takes place in nature as well.

3. The face of the earth constantly experiences rather regular sinusoidal oscillations with a variable amplitude, as takes place in beatings. These oscillations are called microseisms, and their amplitude is usually small, of about 10 μm [3]. However, sometimes the intensity of microseisms increases so that they mask the seismic waves originating in earthquakes. At present, it has been proved that the sources of microseisms are cyclones and typhoons which cause variable dynamic loadings on the ground or water surface. A strong gale can cause microseisms recorded by seismic stations at a distance of 300 km. To evaluate the effect under consideration, we need some characteristics of seismic waves. Thus, the prevailing frequencies lie near 30 kHz (for sandy grounds) and 100–150 kHz (for sandy loams), and the velocity of propagation is ~0.5–2 km/sec (for sand) and 2–4 km/sec (for sandstone) [4].

4. To evaluate forces that act on a body in the ground under the effect of seismic waves and microseisms, we use P. Kapitsa's method of motion in a fast-oscillating field. As is known (see [5], p. 119), this motion can be described by the introduction of the effective potential energy

$$U_{\text{eff}} = U + \frac{m}{2}\overline{\dot{\xi}^2},$$

where U is the potential energy of a constant field (for example, of the field of gravity forces), m is the mass of the body, and ξ is the oscillatory displacement of the body, with the force varying with time at high frequency $\nu >> 1/T$ (T is the order of magnitude of the period of motion which the body could exert in one field U). Assuming that $\xi \sim A$, where A is the amplitude of the seismics, we estimate the second term:

$$\frac{m}{2}\overline{\dot{\xi}^2} = \frac{m}{2}\overline{\left[\frac{d}{dt}A\sin(\omega t)\right]^2} = \frac{m}{2}\overline{[A\,\omega\cos(\omega t)]^2} \sim \frac{m}{4}A^2\omega^2 .$$

In this case, for a body of ~1 kg we obtain

$$\Delta U \sim 1 \cdot (10^{-5} \cdot 2\pi \cdot 30 \cdot 10^3) \sim 3.5 \text{ J}$$

which is quite comparable to U.

So, additional forces which affect foreign inclusions appear in a fast seismic field. These forces can, in principle, expel the body upward to the surface. We note again one important fact mentioned above. Indeed, the addition of energy due to the effect of microseisms is equal to ~m, just as the force of gravity, and it may seem that any inclusions will move similarly. However, we are interested in the case of rare inclusions to a quasihomogeneous lengthy structure; then the effect of expelling will be significant only for fragments.

Thus, two approaches – energy and dynamic – explain the presence of the effect of expelling of a foreign structure from the ground. The phenomenon described has a purely surface character, since surface waves (as is shown in seismology by the example of the so-called Love waves [3]) weaken with distance to a lesser extent than volumetric waves.

REFERENCES

1. R. I. Nigmatullin, *Dynamics of Multiphase Media* [in Russian], Vol. 1, Moscow (1987).
2. I. N. Aliev and P. P. Poluéktov, *Poverkhnost'*, No. 3, 104-108 (1994).
3. F. P. Saverenskii and D. P. Kirnos, *Elements of Seismology and Seismometry* [in Russian], Moscow (1949).
4. I. S. Berzon and A. M. Epinat'eva, *Dynamic Characteristics of Seismic Waves in Real Media* [in Russian], Moscow (1962).
5. L. D. Landau and E. M. Lifshits, *Mechanics* [in Russian], Moscow (1965).