Acoustic Method of Division of Ultradispersible Powders

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Abstract. It is known that nanodispersible powders are the condensed medium which at the same time have properties of liquid and solid bodies. And properties of such an environment strongly depend on particle size. In this work, the acoustic method of division of ultradispersible powders on the fluctuating plate is considered. The experimental data by the efficiency of the division of nanoparticles of dioxide of silicon are obtained. Based on a method of successive approximations of the Navier-Stokes equations for vorticity the equations and boundary conditions for the fluctuating plates taking into account amplitude to the second-order are received. Using the Mathematica system, analytical decisions are received and plots of vectors fields of speeds for a plate of the infinite length are constructed.

1. Introduction

The majority of methods of production of nanopowders give a product with very wide distribution by the sizes that do a relevant division of powders according to particle sizes. In view of very small mesh size and mass of particles of nanopowders the known methods of division either are applicable restrictedly or are not applicable absolutely.

In 1787 Chladni showed that at the fluctuation of a plate a bow of a particle of sand self-organizing symmetric structures form. It was also noticed that more shallow particles of sand accumulate on a crest of fluctuations of a plate. The physical reasons for particle size distributions are bound to streams of air or other environments which is over a plate. Recently there was interest in these streams within the creation of minifans in the form of the vibrating plates of the infinite and finite lengths for microelectronic devices, so, models of gas streams are received in work [1]. In work [2] the idea of Chladni is applied in nanomechanics to a division of nanoparticles according to the sizes by acoustic waves of different frequencies, however for very high frequencies and small sizes of a plate that is almost inapplicable.

In this work the possibility of division of nanoparticles on a plate of a rather big size and with low frequencies is shown, and on the basis of the method of successive approximations [3] of the Navier-Stokes equations for a vorticity the equations and boundary conditions for fluctuating plates taking into account amplitude to the second-order are received. Through the Mathematica system analytical decisions are received and the streams of vectors fields of speeds for a plate of the infinite length proving particle sorting by an acoustic method are constructed.
2. The experimental part
As in our case practical division of nanopowders according to particle sizes matters, as the fluctuating plane the beam (cantilever) length of which much more than its width is used. Since one end the cantilever is excited by transverse vibrations with his resonant frequency 1.035 kHz. On a surface of a cantilever nanopowder of dioxide of silicon, which was redistributed to nodal lines and in the form of clouds in crests (Figure 1), is sprayed.

![Figure 1. The fluctuating cantilever with silicon dioxide nanopowder on the surface](image)

In figure 2 distributions by the sizes of the powder which is selected from nodal lines and from crests, the light scattering received by the method is represented. The experiment series of distributions by the sizes was carried out. The average size of powder was of nodal lines 65µm (so big size is caused by the agglomeration of particles), in crests – 3.5 µm. The division of powder according to the sizes is obvious.

It is expedient to make the calculation of vector fields of gas streams over a surface of this cantilever in view of the fact that the division of powder according to particle size on it is confirmed experimentally.

![Figure 2. Distribution by the nanopowder sizes from the nodal line (a) and from a crest (b)](image)

3. Numerical modelling of gas streams over a plate
We will consider a plate vibrating in the longitudinal direction under the law \( y = w(x,t) \) with amplitude \( A \ll 1 \) and harmonic frequency \( \sigma \).

In a two-dimensional flow of viscous incompressible fluid, the vector of vorticity has only one nonzero component:

\[
\omega_z = \omega = \frac{\partial U}{\partial x} - \frac{\partial V}{\partial y} = -\frac{\partial^2 \psi}{\partial x^2} - \frac{\partial^2 \psi}{\partial y^2} = -\nabla^2 \psi ,
\]
where flow function \( \psi(x, y) \) is defined as follows:
\[
U = \frac{\partial \psi}{\partial y}, \quad V = -\frac{\partial \psi}{\partial x}.
\]

Further from Navier-Stokes's equations it is received the equation for a vorticity:
\[
\frac{\partial \omega}{\partial t} + U \frac{\partial \omega}{\partial x} + V \frac{\partial \omega}{\partial y} = \nabla^2 \omega,
\]
where \( \nu \) – kinematic viscosity.

Using the method of successive approximations [3] we decompose flow function:
\[
(1, 2, 3) = (1) + (2) + (3) + \ldots.
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In calculations the following data were used:

\[ w(x, t) = A \cos \left( \frac{\pi x}{L} \right) e^{j \omega t}, \quad j = \sqrt{-1}, \nu = 1.45 \times 10^{-5} \text{ m}^3 / \text{s}, \quad L = 6.5 \text{ cm}, \quad A = 0.08 \text{ cm}, \quad \sigma = 120 \pi \text{ rad} / \text{s}. \]

4. Conclusion

It is experimentally shown that the division of nanoparticles according to the sizes into surfaces of the fluctuating plate is possible and with a frequency of about 1 kHz.

Numerical modelling taking into account decomposition on amplitude to the second-order shows (figure 4) that streams over the fluctuating plate have vortex structure with the period equal L/2. The next whirlwinds rotate in mutually opposite directions with the centers near a plate. Outflow comes from a plate in the neighborhood of nodal points, and dribble to a plate in the neighborhood of crests of a standing wave where particles of shallow fraction in the form of round clouds (figure 1, figure 2) accumulate.

References

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