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TRIBOLOGY AND ADHESION OF PARTICLES IN ACOUSTIC FIELD

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ABSTRACT
During acting the air flow by the acoustic field, in which hard particles of 10 micrometer size move, and due to their oscillations particles collide between their in the flow. After collision of partidles of different masses, slipping takes place in their contact point accompanied by tribological processes and adhesion forces originate, due to which particles conglutinate. Typical collision of two particles of different sizes under action of the acoustic field is described in the paper. It is shown, that acoustic field parameters have influence to approaching of participles and adhesion conglutination.
Keywords: acoustic coagulation, adhezy force, particle, tribology.

1. INTRODUCTION
Particle coagulation in acoustic field due to the contact physics and chemistry. Colliding particles during the contact surfaces, specifically the rise in some of their surface (in the molecular level). In these points are very high pressure and the local effect of adhesion [1]. Local adhesion strength is such that the relationship is usually terminated not at a point of contact, but the inside of the material. In order to get sufficient adhesion between the particles, the distance between the molecules must be extremely small, nanometric row.
Colliding particles at the beginning acting of traction force on the vandervals effects. Known [2] that, at the distance 1 - 2 nm, vandervals force disappears. Therefore, the adhesion necessary convergence of the particles. For this purpose, using the acoustic field [3]. All solid and liquid bodies have surface forces, therefore, must occur between them the adhesion, but adhesion is sometimes absent. Currently, the generally accepted theory of adhesion is not, there are only a few theories [4, 5, 6]. Authors [4] found that forces between molecules operating at 2 nm distance, and the traction between the particles was observed to 1000 nm. In this way, without forces between molecules, an important role in particle adhesion conduct electric double layer resulting from the contacting particles.
Thus, the electric theory [4] explains that there are additional sources of adhezinių forces [2]. Author [5] developed a recrystallization adhesion theory, which is suitable for crystalline materials. Many of crystalline particles in immediate contact and adhezian merger impedes particle oxide surfaces skin. Energical adhesion theory [6] more suitable for materials with metallic contacts. Z. Lengmiur adsorption theory more suitable for the phase and limits the particles in contact with them to protecting the air, or liquid molecules and the interaction of air or liquid-phase molecules of the particles ahdezes. Thus, there may occur in the sorption, such as Physical and chemical adsorption.
In the case of adhesion theories of diversity necessary to explore the acoustic field effects to airborne particles for the adhezion.

2. OBJECT RESEARCH

Suppose that the sound pressure acting two different masses of solid particles, which we observe from the center of mass system. Under the impact law, derived from the impuls and energy conservation laws, particles can move only so that each retains its original size of the speed, but they can only change the direction of movement. A typical two-particle collision is shown in Figure 1.

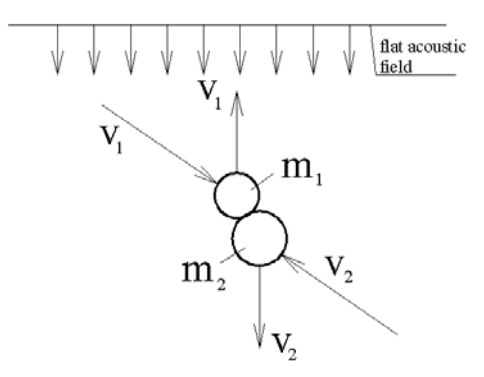

Figure 1. Collision of two dissimilar particles, as viewed from the center of mass system

Moving particles in air flow, and past collide after a certain period of time, some particles moves vertically. After other collision they also change the angle of movement. This way, some particles in the stream after the collision coagulates and the forces of gravity, will fall them down. Thus, the speed of mass centers:

$$V_{mc} = \frac{(m_1 v_1 + m_2 v_2)}{(m_1 + m_2)}. \tag{1}$$

Here V_{mc} – the speed of mass centers; m_1 – the weight of the first particle; m_2 – the weight of the second particle, v_1 and v_2, the corresponding speed of mass.

Relative collision velocity is equal to $U = v_1 + v_2$ (1 fig.). When the particles collide, the mass center is moving at the same speed without change.

This means that $(U \cdot V_{mc}) = 0$. This scalar product can be expressed in terms of v_1 and v_2:

$$U \cdot V_{mc} = \frac{(v_1 - v_2)(m_1 v_1 + m_2 v_2)}{m_1 + m_2} = \frac{(m_1 v_1^2 + m_2 v_2^2) + (m_2 - m_1)(v_1 v_2)}{m_1 + m_2}. \tag{2}$$

Acoustic fields faced particles in the process of contacting normal and tangential forces appear micro movement. Then the surface of section will be operational in molecular surface forces, forming adhezed mergers. In such a tribological situation, does the beginning of traction force, thus vandervals effects. It is believed that the adhesion force vandervals operates between all the materials, which can bring together the sequence of nanometric distance [1].

Thus, based on the momentum conservation law, can write that:

$$v_2 = v_1 \frac{m_1}{m_1 + m_2}. \tag{3}$$

It follows that the coagulated particle velocity will be less than the speed of the impacted particle.

3. ACOUSTIC RESEARCH

Flat acoustic waves (fig. 1) wave equation describing the elastic excitation, has the form [8]:

$$\frac{\partial^2 a}{\partial t^2} = c^2 \frac{\partial^2 a}{\partial z^2}, \tag{4}$$

here *a* – srauto dalelių poslinkis rimties būvio atžvilgiu; *t* – time; *c* – speed of sound; *z* – coordinate. Partial equation (4) solution will look like this:

$$a = A \sin \omega \left(t - \frac{z}{c} \right), \tag{5}$$

here *A* – displacement amplitude; *ω* – angular frequency.

Equations (5) describes a flat harmonic wave, with frequency $f = (\omega / 2\pi)$ and spread the positive z–axis direction. Differentiate equation (5) according to t we get the speed of particles:

$$u = \omega A \cos \omega \left(t - \frac{z}{c} \right), \tag{6}$$

and differentiate second time, we get the particles acceleration:

$$b = -\omega^2 A \sin \omega \left(t - \frac{z}{c} \right). \tag{7}$$

In these equations are velocity and acceleration amplitude is $U = \omega A$ and $B = -\omega^2 A$.

Particle adhesion depends on the intensity of the sound [3], which according to [8] is as follows:

$$J = \frac{1}{2} \rho c U^2, \tag{8}$$

here ρ – flow density.

From the equation (8) can be found in *A*, *B* and *U* values.

According to the second Newton's law of motion, we can write, that the force acting volume unit in the sound wave and that equal of pressure drop:

$$\rho b = -\frac{dp}{dz}. \tag{9}$$

Estimates of equation (7) we get:

$$-\rho \omega^2 A \sin \omega \left(t - \frac{z}{c} \right) = -\frac{dp}{dz}. \tag{10}$$

Integrating (10) according to the z, we find the sound pressure:

$$p = p_0 + A \rho c \omega \cos \omega \left(t - \frac{z}{c} \right). \tag{11}$$

Here p_0 – pressure, when there is no impact on the acoustic field.

Value $P = \omega\rho cA = \rho cU$ called the sound pressure amplitude.

After making the calculations according to (8) and (5) we obtain the equations particles amplitudes shift in acoustic field, depending on the frequency and intensity of the sound.

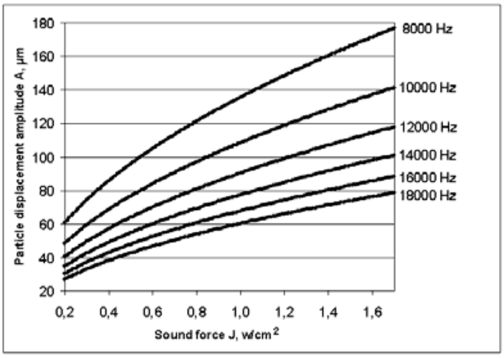

Figure 2. Particle displacement amplitude dependence of sound force in air in 3 – 18 kHz range

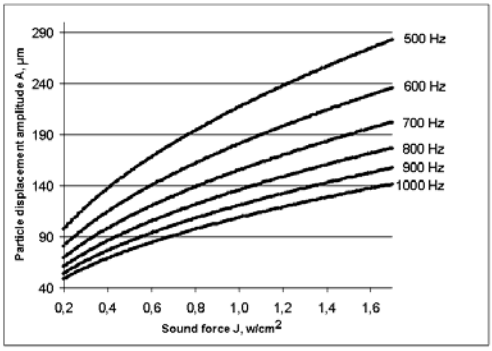

Figure 3. Particle displacement amplitude dependence of sound force in air in 0,5 – 1 kHz range

4. CONCLUSION

Research shows that particle motion in acoustic field is dependent of sound intensity and frequency. In the case of different frequencies, the amplitude shifts of particles ranging from 20 to 285 micrometers. The growing intensity of the sound particles shifts the amplitude increases.

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