The two-dimensional acoustic standing wave and its application in a coagulation of aerosols

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Abstract: This paper deals with the problem of a transversal drift of aerosol particles in the high frequency stationary two-dimensional acoustic field. We propose a qualitative explanation of this phenomenon and formulate some postulates towards construction of its model.

FORMULATION OF THE PROBLEM

The phenomenon of drift of small particles suspended in a gaseous medium in which the acoustic wave propagates, is known since long, and was explained for the first time by King [3], who adopted the radiation pressure as its principal mechanism. The drift force was related in this model to the diffraction of the wave on the particle. However, it became evident that theoretical results are consistent with experiment only for relatively big particles, while small particles do also drift and gather, depending on their relative density, in nodes or loops of the standing wave.

Numerous explanations of this fact were published. Particular theories adopted, as a reason of the drift of small particles, various second order effects competitive with respect to the radiation drift described by King. As an example, let us recall the viscosity drift, related to periodical variations of the temperature, and thus viscosity, in an intensive acoustic wave field, or a drift connected with presence of higher harmonics in the wave spectrum. The most natural explanation for the drift of small particles in the standing wave field, applicable in wide range of radii and frequencies, came within the theory of the so-called asymmetry drift, related to the nature of the standing wave itself [1]. In short words, a particle performs quasiharmonic vibrations with some phase delay with respect to the medium vibrations (in case of the plane wave, this is the motion in the direction of the wave vector). Because of finite amplitude of its vibration, it experiences different action from the medium in both limiting points of oscillations less, when the particle is closer to the node of the acoustic velocity, and greater, when it is closer to the loop. Let us recall that the source of the particle-medium interaction in this model is simply the Stokes force. The method of solution of the problem consists in consideration of the equation of motion of a particle influencing the Stokes force depending on particles position and the inertia force.

Dain et. al. [2] noticed that in the case of two-dimensional standing wave, i.e. such of non-planar wavefront, the aerosol particles, besides the movement towards planes of maximum velocity amplitude of the medium (loops), perform also a kind of transversal drift, i.e. move tangentially to the wavefront. The deviation of the wavefront from the plane in [2] was reached two ways: naturally, as a result of friction phenomena in the neighbourhood of the vessel, and by proper transducer/reflecter configuration. The authors observed that in the case of concave wavefront, the particles drift towards walls of the vessel, while with the convex wavefront towards the centre of the vessel.

It is easy to see that, considering the position of a particle in the standing wave field (understood as a combination of progressive waves such that at certain surfaces the velocity amplitude is still equal to zero, while at others reaches maximum), it is impossible to define if the wavefront is convex or concave. It would be possible, of course, in the case of a non-planar progressive wave, where a surface could be described as convex or concave with respect to the wave vector direction. Therefore, the only reason of different behaviour of particles may result from differences in different geometrical properties of these surfaces.
POSTULATES

From this point of view, one may formulate the following postulates:

1. The observed transversal drift could be applied in dust removing installations. The transversal drift concentrates the particles not only at certain surfaces, but also at certain points. This means intensification of the coagulation effect, which is essential for all dust purification processes.

2. These points must be, with no doubt, some characteristic points of the surfaces form the point of view of the differential geometry. The points should be identified as points of suspension particle concentration by means of some quantitative or qualitative physical considerations.

3. To obtain a drift, a kind of asymmetry is necessary. It is obvious that drift will not occur in the spherical standing wave. Therefore, one may postulate that in order to solve the problem, it is sufficient to adopt the above described drift mechanism, taking into account the asymmetry of the standing wave in two dimensions.

4. For both creation of a mathematical model and its experimental verification, one has to examine the problem of non-planar standing wave. As far as we are concerned, this problem is not represented in the standard literature.

EXAMPLE

The two-dimensional standing wave configuration seems to be of special interest. In the case when nodal and antinodal surfaces of standing wave are convex the particles gather in some particular points. The concentration of particles increases around these points and makes the acoustical coagulation more intense. This is the principle of technical application of the phenomenon. It is shown that the drift of the particles in the case of two- or three-dimensional standing wave depends on the acoustic velocity and on the frequency. We propose for example the standing wave in a rigid elliptical cylinder with strip-shaped source of uniform velocity distribution placed in the symmetry plane of the system. This case could be probably applied with success in technical installation for coagulation of aerosols. Some results of numerical examples will be presented during the symposium. We will also suggest some technical solutions which seem to be optimal from economical point of view.

REFERENCES