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A NEW WAY OF COARSE MATERIAL DEHYDRATION

The method for removing moisture from the surface of the particles of coarse material by the action of high-speed vortex flow is proposed. In this way, particles acquire rotational motion with high angular velocity and moisture falling from the surface is picked up by the air stream and carried out of the zone of separation. A construction of the apparatus for carrying out the method is worked out, and the results of its tests to confirm the high efficiency of the developed method of dehydration are presented.

Introduction. In the chemical, food-processing, and other industries, the final or intermediate product is often produced in the form of large crystals or granules. Such products should include ammonium sulfate, potassium chloride, sodium chloride, polyethylene, polystyrene, sugar and many others. All these materials are first prepared as dilute suspensions. To obtain a dry product, the suspension is condensed first and then it is passed over to the filter or centrifuge, and the final state dehydration is carried out by drying. It is known that drying is an expensive process requiring significant heat input. Therefore, when suspensions are dehydrated, it is desirable to remove as much as possible moisture in centrifuges or filters, as mechanical or hydro-mechanical processes of dehydration are always several times cheaper than the thermal drying process [1].

If we analyze the humidity of the above mentioned materials after centrifugation, it should be noted that it is low and does not exceed 10%. However, when drying, heat is consumed not only for moisture evaporation, but also for heating the material, taking into account heat loss to the environment. Therefore, the heat consumption in the drying stage is significant and, consequently, the cost of this process is high. Analyses of moisture bond with crystals and polymer granules shows that it is basically mechanically bound moisture on suitable surface particles as a result of wetting, and it is not strongly associated with the material [2].

Main part. The aim of our study was to investigate the possibility of removing surface moisture from crystals or polymer granules in a cheaper way. For this purpose, the idea of an aerodynamic influence on the particles with the air stream to bring to them to a rotational motion with a high angular velocity was proposed. In this case, the surface moisture will break away from the surface of the particles in the form of tiny droplets. The next problem to be solved is removal of fine liquid droplets together with the air from the zone of interaction of the particles with air. To study the conditions under which the solid particles can acquire rotational motion in the gas stream, the motion of two-phase flows, and in particular the movement of solid particles in gas flows were analyzed [3–6]. The results of numerous theoretical and experimental studies have shown that the particles of the particulate material in the two-phase flow may acquire the rotational motion [5–8]. The rotational speed of the particles can be very high and it can amount to tens and hundreds of thousands of revolutions per minute. For example, corn, soybeans and wheat in pneumatic transport can be rotated at a velocity $7 \cdot 10^3$–$20 \cdot 10^3$ rev/min [7], and fine particles of 0.06–0.40 mm size at the outflow of the two-phase flow pipe can make up to half a million revolutions per minute [6]. There are many reasons why the particles begin to rotate in the gas stream, some of them we will analyze in detail.

To acquire rotational motion, the particle in a gas stream should gain impulse as a pair of forces. Such impulse may often occur due to asymmetric impact on the particle gas stream or the tangent hitting against the wall. Moreover, the rotation may be caused by mismatch of the gravity center with the action center of the aero-dynamic resistance; it is essential for the particles of irregular shape. Moving in the gas stream polydispersed particles constantly collide with each other. After tangential collision particles also start to rotate. However, the subsequent collision with another particle can slow down the rotation or change its direction. The above mentioned factors that cause the particles to rotate in the moving gas stream can operate in any combination. Obviously, the match of the action direction of the impulses twisting the particle arising from various causes can be considered an exception.

The exact determination of the angular velocities of particles, especially for polydispersed materials is almost impossible. This requires a thorough analysis of regularities of translational motion of some particle based on its interaction with the channel wall and other particles, as well as take into account the influence of many factors and combinations equally affecting the rotation of the particles, that is practically impossible. To assess the impact of each factor on the speed of rotation of the particles preliminary calculations with a number of the assumptions were carried out, which showed that the maximum speed of rotation of the particle reaches the tangent at the collision with the wall , as well as when it is acted upon by the high-gradient air gas flow. This problem can be solved by supplying the particles in a high speed vortex gas flow. In this case, the particles will be involved into a swirling motion and due to the centrifugal force will be rejected at a high rate angular to the wall, and in the motion of it will be exposed to high-gradient air gas flow.

Considering the above described requirements on giving material particles the high-speed rotary motion, it was designed the apparatus for deep dehydration of coarse-grained material, which is presented in Fig. 1. The apparatus consists of a cylindrical shell *1*, which is held in the upper part on a tangential air supply pipe *2*. The top cylinder shell is closed by lid *3*, through the centre passes pipe *4* for supplying wet material inside the apparatus. At the exit of pipe *4* there is a conical bump *5* to dispense the material. To the bottom of the cylindrical shell *1* a perforated conical shell *6* is fixed tapering downward and ending with unloading pipe *7*. For droplet liquid precipitation from the air there is chamber formed by shell *8* with bottom *9* and lid *10*. Removing liquid is carried through pipe *11* and air – through pipe *12*.

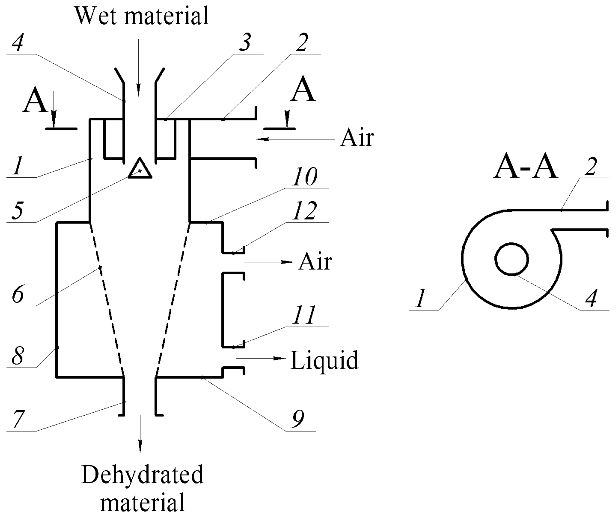

Fig. 1. Schematic diagram of the apparatus

The process of removing moisture from the surface of the particles is as follows. Air is supplied tangentially through pipe *2* into the cylindrical portion of the apparatus, whereby it also acquires down and forward whirling motion, resulting in an exhaust in the center of the device. Wet material is supplied through pipe *4*, hits the conical bump *5* and dispersing, and falls into a vortex gas flow. This material is dispersed into individual particles that are drawn into the gas flow swirling motion. Due to centrifugal forces generated by the vortex motion, the particles will be thrown to the wall. When moving to the wall, the high-gradient particle will be affected by the gas flow. Big difference between the velocities of gas on both sides of the particle causes it to rotate. Reaching the wall, the particles have a fairly high speed and hit it at an angle; that gives an additional impulse for the rotation. The speed of rotation as previously mentioned, can reach several tens of thousands of revolutions per minute. At these speeds, the moisture on the surface of particles, overcoming the surface tension forces will break away from the surface of the particles in the form of tiny droplets, and it will be taken away by gas flow. When moving in a swirling gas flow the particles constantly collide with each other. Collision between wet particles and strikes against the wall contribute to the moisture breakdown from the surface. Airflow of particles by high speed flow, especially at shock deceleration also facilitates the removal of moisture from the particle surface. It should be noted that the particles having reached the wall, do not move on it, but move along the wall by jumps [9]. And thus, while they fall down, make many blows on the wall. When reaching the bottom of the cone 6, dehydrated particles are moved through pipe *7* out of the device. During the vortex motion of the gas flow at the wall a zone of high pressure is created. Therefore, the air with the liquid droplets reaching the perforated housing passes through the holes, and further to the precipitation chamber; moisture is separated from the gas flow through pipe *11*, and it is removed from the apparatus, and the air rises up and exits through pipe *12*.

Effectiveness of the developed method of wet particles deep dehydration and effectiveness of the apparatus for its implementation in future were checked experimentally. To conduct the experiment, a prototype device was made with a diameter of 0.08 m in the cylindrical portion. The air supply into the apparatus was controlled within the speed change section of the cylindrical portion on the apparatus in the range of 5–20 m/s.

To confirm the assumption that the field of gas flow velocities in the vortex motion has a larger gradient in the cross section of the apparatus, the measurement of the axial and tangential velocity profile was performed according to the known method [9]. Processing of the experimental data to determine the axial and tangential velocity was carried out in dimensionless form:

$$u_z = \frac{u_z}{u_{av}}; \; u_j = \frac{u_j}{u_{av}},$$

where u_z – the axial velocity of the gas flow; u_{av} – the average expendable gas flow velocity on the cross section of the device; u_j – the tangential velocity of the gas flow.

The radius of the apparatus is also presented in dimensionless form:

$$r = \frac{r_t}{R},$$

where R – radius of the apparatus; r_T – current radius.

Full gas flow velocity is calculated according to the known dependency:

$$u_{full} = \sqrt{u_z^2 + u_j^2}\ .$$

The results of processing of the experimental data are shown in Fig. 2, where curve *1* shows the changes of the axial velocity profile along the radius of the apparatus, curve *2* – the tangential velocity, and curve *3* – the total velocity.

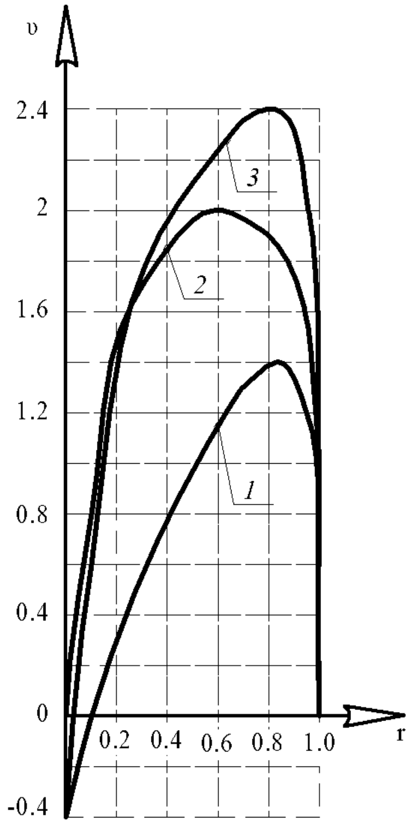

Fig. 2. Dependency diagram of the axial, tangential, and total velocity on the radius of the gas flow

The diagram shows that the value of the axial, tangential, and, hence, the total velocity varies greatly according to the radius. Thus, the axial velocity at the center is of negative value, which indicates the presence of circulating flows, and it reaches its maximum at a distance of 0.95 R. The tangential velocity reaches its maximum at the distance from the center, which is equal to 0.6 R, and this maximum is 2 times higher than the average expendable gas flow velocity in the apparatus. At the wall the axial and tangential velocity is naturally equals to zero, and thus, in this zone there is a sharp drop in gas flow velocity. The measurement of the velocity profile at three points along the length of the cylindrical part of the apparatus showed that it varied very slightly. Thus, the data of the investigations show that the particle moving from the center to the wall, is subjected to the effects of high-gradient gas flow. The magnitude of the gradient in the swirling gas flow velocity is two times higher than in a turbulent flow without swirling.

The final stage of the research is to determine the moisture content of various materials after passing through the developed apparatus. The polyethylene granules with δ = 4 mm size of the particles, polystyrene granules with d = 0.1–3 mm, size of the particles, and sand with δ = 0.1–4 mm. crystal size were used as the investigated material.At the beginning of the experiments, an aqueous suspension was prepared, which is then poured into a grid, where the bulk moisture was drained, and the wet material was used for the experiments. Analysis showed that the initial moisture content was 5.6% polyethylene, 12% polystyrene, 14.2% sand. The difference in the moisture content of the materials is explained by different wettability and particle size. Experiments were conducted starting at 8 m/s at the cross section of the cylindrical portion up to 20 m/s every 4 m/s. Quantity of the supplied material was about 15 kg/h.

When conducting the experiments, the material was sampled before and after the apparatus, they were weighed, further they were dried and reweighed. The moisture content of the material was calculated according to the results of weighing.

In the diagram (Fig. 3) the results of studies on the effectiveness of the material moisture removal depending on the average expendable gas flow velocity were shown.

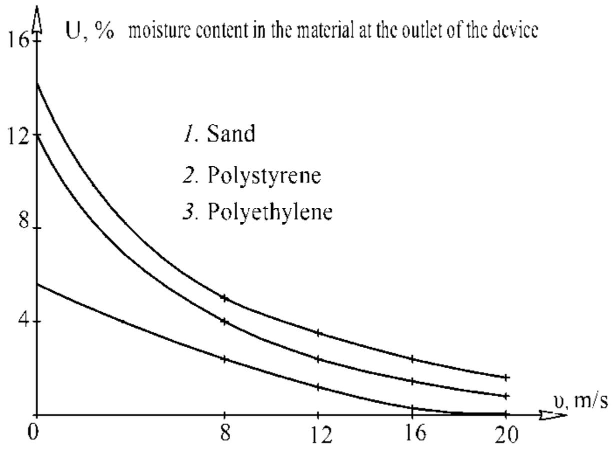

Fig.3. Diagram of moisture content in the material depending on the average expendable gas flow velocity at the outlet of the device

The diagram shows that the moisture content of the material with increasing gas velocity decreases. For example, for polyethylene it is decreased at gas velocity 20 m/s to 0.04%. It should be noted that such humidity in the production is achieved after prolonged drying. At this gas velocity humidity of polystyrene reached 0.8%, and sand – 1.6%. From the diagram it can be assumed that with increasing gas velocity up to 30 m/s, the humidity of polystyrene and sand drops to a minimum, and there will no longer be need for drying.

Conclusion. The study of theoretical and experimental research allowed us to develop a new method and apparatus for coarse material deep dehydration. This method allows us to reduce significantly the cost of drying such materials, and in many cases the drying process can be omitted.

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