FORMOVÁNÍ NANOČÁSTIC VIBRACEMI A AKUSTICKÁ CHARAKTERISTIKA

Aleš PROCHÁZKA, Aleš SLÍVA

VSB – Technical University of Ostrava, Ostrava, Czech Republic, EU
ales.prochazka@vsb.cz, ales.sliva@vsb.cz

Abstract

The effect of vibration is commonly used in many applications and in many manufacturing or handling processes needed to increase the efficiency of various operations such as emulsification, granulation, mixing, etc. The paper deals with a formation of nanoparticles modified titanium dioxide in patterns on a vibrating mesh. The vibrating mesh is characterized by the fact of an air fluidization and also prevents the passage of air. Artificially creating areas on the vibrating mesh through which air can pass through can be targeted to a shape and create formation of resulting granules of nanoparticles. To create vibrations an amplified speaker has been used, in which the sounds have been generated by different constant frequency equal to the natural frequency sieves.Formation of nanoparticles has been carried out not only due to a vibration of a mesh, but above all the action of acoustic waves passing through artificially created area through which acoustic waves can act directly on nanoparticles. Formation of nanoparticles has been examined for the formation of various basic geometric shapes.

Keywords: Vibration; Mixing; Granulation; Fluidization; Titanium Dioxide

1. INTRODUCTION

The behavior of the vibrating bed depends on the particle size distribution, particle density, and the frequency and amplitude of the applied vibration. The flow behavior of the vibrating bed can be classified into four patterns as shown in Fig.1. Type (a) denotes uniform consolidation, type (b) the surface flow near the side well, type (c) the inward circulation, and type (d) the outward circulation.

If a sieve is excited by vibrations with amplitude *A* and angular frequency *ω* in direction to sieve (in the positive direction of the y axis), as depicted in Figure 2, then the length of the translocation of the sieve (membrane) in the direction of the y axis can be determined by relations

$$y = A \sin \omega t \sin(\alpha + \beta) \qquad (1)$$

while the components of the sieve speed in the given directions are given by the first derivation of the translocation components

$$\dot{y} = A\omega \cos \omega t \sin(\alpha + \beta) \qquad (2)$$

and the acceleration components are given by the first derivation of its speeds, i.e. the second derivation of the translocation components

$$\ddot{y} = -A\omega^2 \sin \omega t \sin(\alpha + \beta) \qquad (3)$$

To allow the maximum efficiency of aeration (and hence forming, charging, and vibration) of particles located on the net, it was necessary to first find a harmonic dynamic actuating frequency of the (forcing) external forces which would be identical with the own frequency of the sieve. Finding the own frequency of the sieve is important, since if the frequency of the actuating force approaches the own frequency of the sieve, this will significantly increase the amplitude of oscillations. This phenomenon is called resonance and is based on using resonance to strengthen oscillations. Hence a small, periodic force (actuated by an acoustic pressure wave from the speaker) in the resonance area can create sieve oscillations with large deviations in the amplitude.

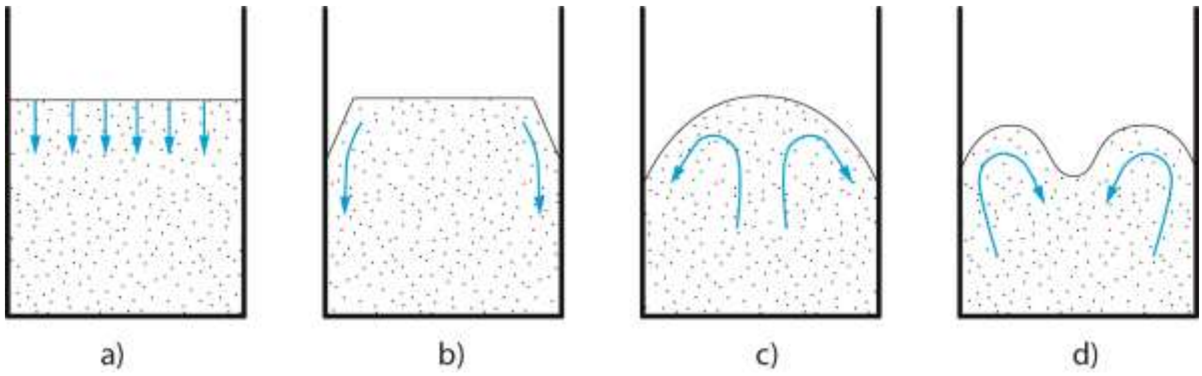


Fig. 1 – Flow pattern of vibrating powder bed.
a) compaction, b) surface flow, c) inward circulation, d) outerward circulation

First, we determined the own frequency of the sieve. Since the sieve is embedded in a frame, it operates as a damped oscillator. Acoustic pressure travels through the punctures, where it hits particles and makes the partially actuated, aerates them. Acoustic pressure which hits the sieve with the same frequency as the sieve's own frequency results in the aforementioned resonance.

2. MEASURING APPARATUS AND MEASUREMENT PROCEDURE

An accelerometer (Omega ACC104A2132) was attached to the sieve (membrabe) 50 mm from the border of the frame (Fig. 2). This membrane is stretched on the aluminum frame. The membrane is made so that it contains areas where acoustic aerial pressure waves caused by vibrations from the speaker can pass through. On this membrane lies the processed soft nanomaterial (titanium white). The speaker emits a pressure acoustic wave towards the membrane in the required frequency. To obtain the own frequency of the sieve, it was first necessary to vibrate the sieve by a certain actuating force. This was carried out, and the accelerometer was used to measure and record the fluctuations of the membrane away from the speaker.

3. ACOUSTIC CHARACTERISTICS – OWN FREQUENCY OF THE SIEVE

The figure 3 below depicts an example of one of the measurements. As shown, the membrane has the highest fluctuations at the beginning of the actuation and the fluctuations decreased over time. The decreasing height of the amplitude of oscillations intersects the timeline always at a specific time period. After deducting these time periods (t_2-t_1, t_3-t_2) and inverting its value, we obtain the required frequency. By averaging the frequencies over all

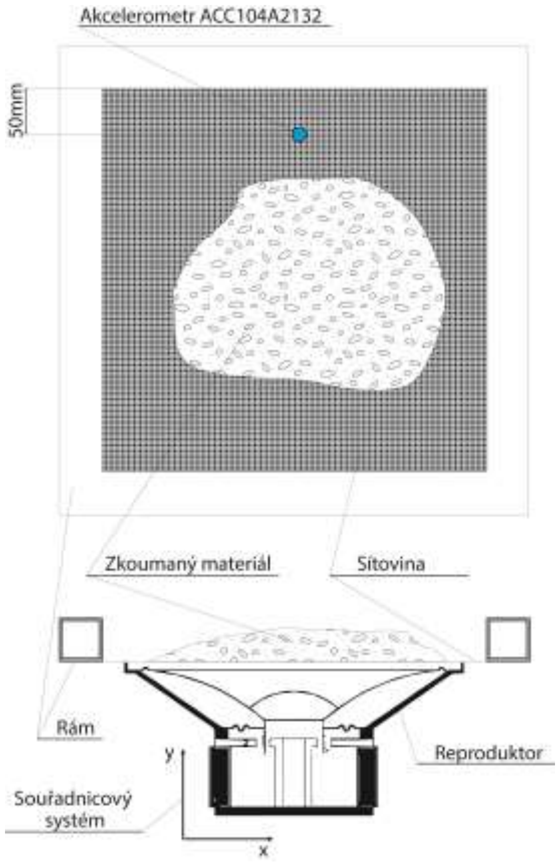
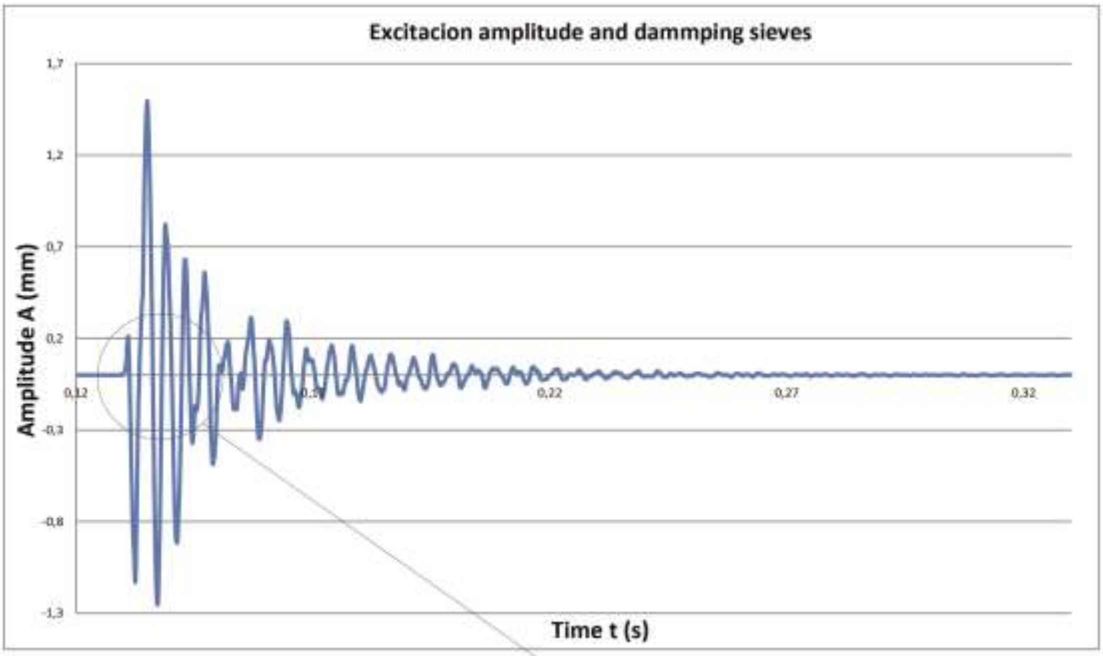


Fig. 2 – Scheme of the experimental equipment.

measurements, we obtain the average value of the own frequency of the membrane used in the measurement.



t_1=	1,130587
t_2=	1,13486
t_3=	1,13899
t_4=	1,9447
t_5=	1,94942
t_6=	1,95322
t_7=	1,13896
t_8=	1,14359
t_9=	1,77423
t_{10}=	1,77925
t_{11}=	1,78404
t_{12}=	1,33031
t_{13}=	1,33528
t_{14}=	1,33992

T_1=	0,00427	»	f_1=	234,0276
T_2=	0,00413	»	f_2=	242,1308
T_3=	0,00472	»	f_3=	211,8644
T_4=	0,0038	»	f_4=	263,1579
T_5=	0,00463	»	f_5=	215,9827
T_6=	0,00502	»	f_6=	199,2032
T_7=	0,00479	»	f_7=	208,7683
T_8=	0,00497	»	f_8=	201,2072
T_9=	0,00464	»	f_9=	215,5172

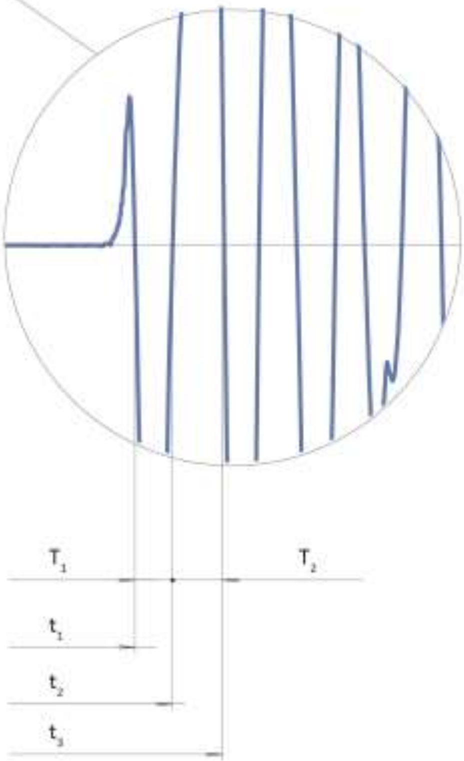


Fig.3 – Example measurements of excited sieve.

$$f = \frac{f_1 + f_2 + f_3 + f_4 + f_5 + f_6 + f_7 + f_8 + f_9}{9}$$

$$f = \frac{243.03 + 242.13 + 211.86 + 263.16 + 215.98 + 199.2 + 208.77 + 201.21 + 215.52}{9}$$

$$f = 222.32Hz$$

4. MODIFICATION OF PARTICLES

The experiment of forming nanoparticles through acoustic pressure waves was carried out for R972 and TiO_2 particles. TiO_2 is characterized by the fact that when stored it has a tendency to cohesive behavior and is also very hard to aerate, and hence its manipulation often leads to clogging of devices. To improve its manipulation properties, it is necessary to improve the so-called internal friction angle (flow properties) of these particles; this is carried out through R972 particles, as depicted on Fig. 4. Fig. 4 shows TiO_2 particles on the top right and top bottom which were modified by R972 particles (Fig. 4 top left and bottom left).

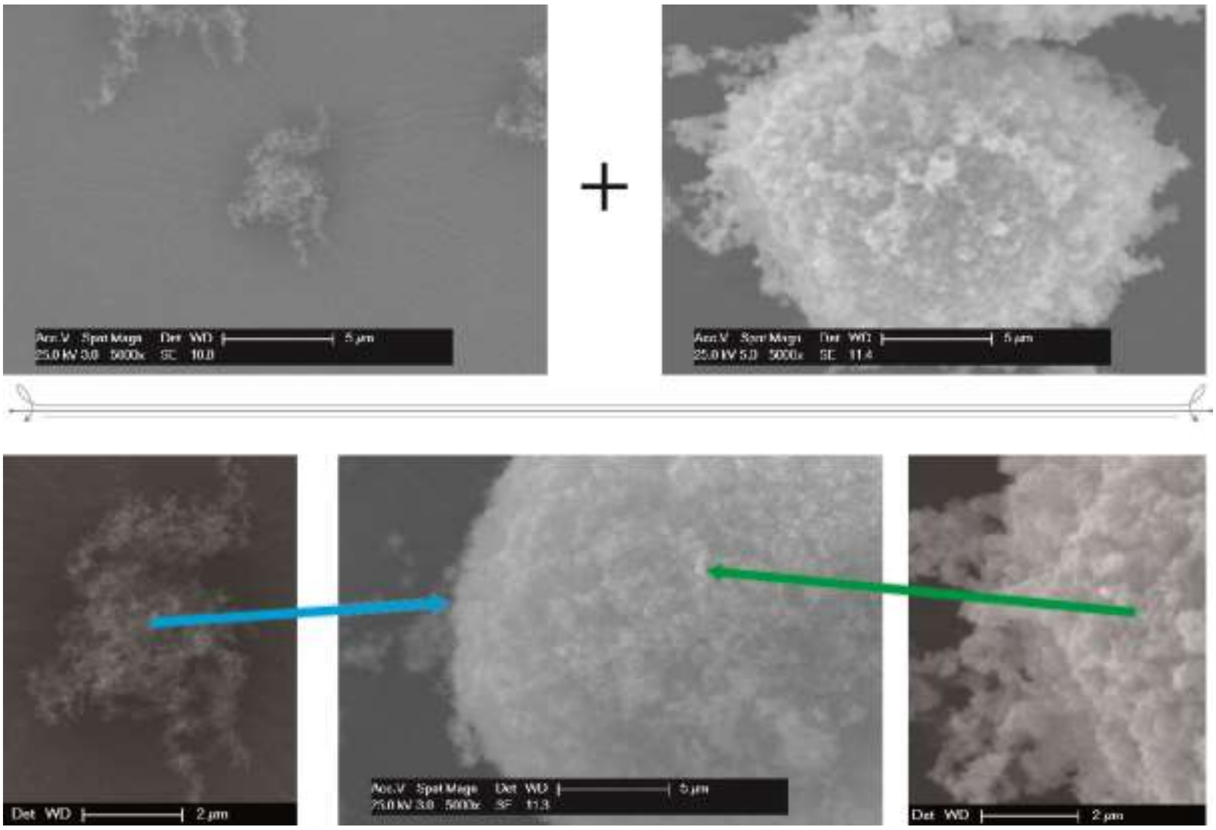


Fig.4 – Particles R972 (top left and bottom) and TiO_2 (top right and bottom) and modified particle TiO_2 particle R972 (bottom middle).

The resulting modified particle is depicted in the bottom-middle part of Fig. 4. The resulting particle has approximately the same shape, and is basically a TiO_2 particle covered by R972 particles. R972 particles are uniformly distributed first into the surface pores and then over the whole surface of the TiO_2 particle, resulting in the homogeneous and uniform covering of the TiO_2 particle by R972 particles, which the TiO_2 particle completely different surface properties. The property characterizing the TiO_2 particle, i.e. its whiteness, remained unchanged, since R972 particles are virtually transparent. Changes of surface properties (modification) result in an improvement of the flow properties of the material by approximately 50%.

Fig. 5 – Mixing of particles R972 and particle TiO_2 acoustic vibrations.

Figure 5 depicts an experiment mixing TiO_2 and R972 by an acoustic pressure wave emitted from a speaker. The experiment took approximately 10 seconds and visibly improved the flow properties of TiO_2 by about 50%.

5. FORMING OF NANOPARTICLES

If we want to create an arbitrary shape of a nanoparticle consisting of smaller nanoparticles, we can use the 10,000 year old technology of sieve-printing and granulation. The size of the netting needs to be minimized so that the size of the mesh transmitting the acoustic pressure wave does not exceed the size of the smallest nanoparticle, to prevent unwanted pass-through of nanoparticles.

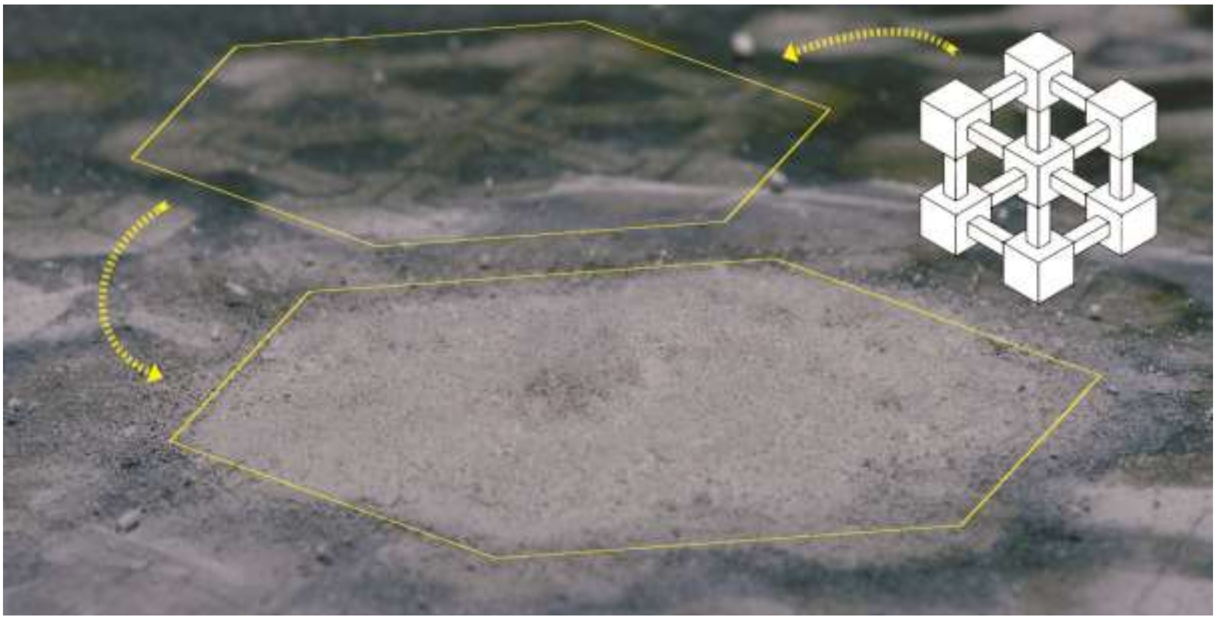


Fig.6 – An example might look as desired structure (upper right corner), which is transmitted as a template for the sieve (top center) looks and the resulting structure (bottom center).

By combining these techniques, it is possible to create an arbitrary required shape the nanoparticles are to be arranged into. Afterwards, it suffices to send the required acoustic pressure wave with the required frequency and force to travel through the sieve and hence actuate the nanomaterial. The actuation should be in a range preventing the unwanted escape of nanoparticles. Once the nanomaterial is actuated, we can use e.g. dispersion of droplets to distribute the bonding agent, which will uniformly and homogeneously cover the nanoparticles located only slightly above the sieve. The nanoparticles will become heavier and land on the sieve between other, previously coated nanoparticles. When landing, the nanoparticles will create bonds by liquid bridges in the required shape.

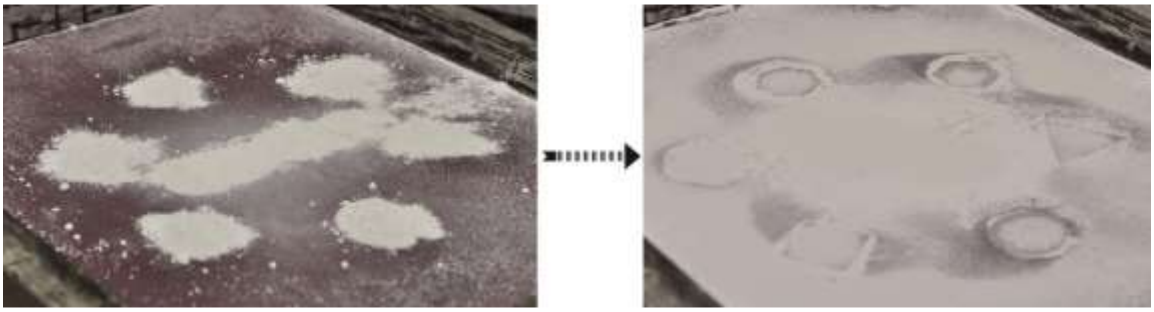


Fig.7 – Example of basic geometric shapes for serving any shaping of the particles.

Particles located outside of the area with the created holes are not in the same actuated state as the particles located above the holes, and hence they are not homogeneously covered – instead, only the highest layer of nanoparticles located on the sieve are coated. After the bonding agent dries up, the required shape of nanoparticles can be simply removed from the sieve e.g. by once again actuating the sieve by vibrations through the used speaker, hence disrupting any unwanted force holding the nanoparticles on the sieve. Fig. 6 depicts an example of a required structure and the resulting structure (for now without coating) after approximately two seconds of emitting the required frequency of 222.32 Hz. Fig. 7 also shows a few examples of forming other shapes (text, company logos, 3D bodies etc.).

CONCLUSION

Nanoparticles can be formed into interesting shapes by vibrations and aeration caused by an acoustic wave with a certain frequency, for instance into the shape of numbers, allowing the marking of products of very small sizes. The creation of the required shapes or paths from nanoparticles can also be used for the production of printed connections in microprocessor technology, where minimization of the size of individual parts is of great interest.

LITERATURE

[1] TAMURA, S. and AIZAWA, T. Granular particle modeling for ceramic powder behaviour in consolidation and sintering, *Advanced Materials,* 1994, Pages 507-510.