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Analysis of aerosolic development process

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Introduction

Application of precise vibration mechanics and corresponding technical principles, has a considerable influence on creating high efficiency technologies, relating new production quality.

Transportation solutions of various materials with a help of vibrations make possible to create many transportation – dosing mechanisms [1,2].

The development of new technologies and machine components, is based on the application of smart materials with controllable characteristics. The following features of artificial intelligence of precise machines and mechanisms are being developed: adaptive ness, multi-diagnostic, self-repair.

Precise micromechanics is used in various technological processes, industry (glass, paint manufacturing, powder metallurgy) medicine and pharmacy, which enables precise dosing of small portions. Precise vibration devices for fluid and powder material dosing can be effectively used in new science and practice field – monodispersion technology [3,4]. It is based on generation of precisely dosed drops, creating various automatic dosing systems for dangerous, toxic and nuclear materials. Medicine, pharmacy, electronics and other branches need such dosing devices.

Investigation model of the system

The aerosolic development process of an electrostatic hidden image consist of two main phases: 1– pulverization developer on the development area and changing particles of aerosol; 2 – precipitation particles on the surface of photoconductor with hidden an electrostatic image.

Aerosol is the dispersion system which consists of small particles with dimensions from 0,1-10 μm in dispersion phase and gas phase where particles are in suspended condition. Aerosols could be divided in two groups: smoke and mist. The smoke includes solid particles and the mist includes liquid particles, which are in intensive motion, because of the heat. The particles of aerosol are precipitated very fast, because of gravitational force and because the density of particles differs from the gas density of particles. The particles are sticking together and this negatively affects quality of development.

The aerosolical development can be with electrode or without. The electrode has to be used in the cases where there are requirements for the same intensity on the duplicate and origin. In this investigation the electrode as a grid was used.

The device consists of the vibro pulverizer (Fig. 1) which includes piezoelectric vibration converter (1,2) in the shape of cylindrical piezoelement and working part where the aerosol 3 is created [2].

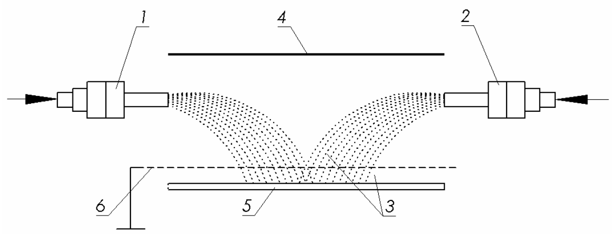

Fig. 1**. Scheme of aerosolical development device: where 1, 2 – precision doser - pulverizer; 3 – liquid particles of aerosol; 4, 6 – electrode; 5 – area of development process**

The aerosol is participated on the surface 5, because of the electrostatic field between electrode 4 and development surface 5.

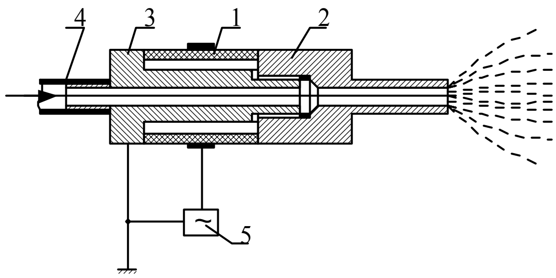

Fig. 2**. Precise vibro pulverizer: where 1 – piezoelectric elements; 2, 3 – electromechanical converter; 4 – inside channel; 5 – signal generator**

The dozer – pulverizer consists of the piezoelement 1, the concentrator 2, 3, the main channel 4, and the signal generator 5.

The vibrations, which are excited in the concentrator are affecting the flowing out liquid and converting to the aerosol torch. The process of electric charge to aerosol particles and their precipitation on the development surface is investigated.

The purposeful ions movement to aerosols particles are stimulated by external electrical charge and are stimulating diffusion process on the plate's surface [5]. The process depends on measures dimensions of particles. The particles with radius $r \geq$ 2-3 μm are most influenced by purposeful ions movement and the diffusion of ions can be neglected. When the radius of particles is $r <$ 2-3 μm, the process of diffusion and impact of charges must be taken into account. When the radius of particles is

r < 0,1 μm, the diffusion process has main influence. Investigating dispersion of aerosols with the precise dozer pulverizer it was established that the diameter of aerosol particles is from 2 to 5 μm and only few ones have the diameter 10 μm [2].

Fig. 3 shows dependence of the liquid pulverizing speed on changes of resonance frequency of the pulverizer excitation and the voltage of excitation for different values of a liquide pressure.

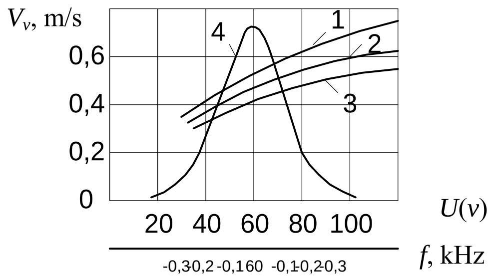

Fig. 3. **Dependence of the everage steady speed v_v of liquid, pulverized by the precise vibro-pulverizer, on the frequency of oscillations (4) and the voltage of pressure of liquid 1- 5 kPa, 2- 10 kPa, 3- 20 kPa**

Investigation of aerosol's particles charging process

The main developing process is going on because of purposeful ion's movement towards particles in an external electric field. But only ions which are moving lengthwise strength lines and intersect surface of particles reach the surface of particles of aerosol. This process when the diameter of particles is 2-5 μm is investigated in the article [6]. Referring to the article [6] the charge q of a particle is given by:

$$q = 4\pi\varepsilon_0 E_a \left(1+2\frac{\varepsilon-1}{\varepsilon+2}\right) r^2 \frac{\eta e n_0 t}{4\varepsilon_0 + \eta e n_0 t} \qquad (1)$$

where E is the strength of the electric field; ε is relative dielectric material permittivity of particles; ε_0 is the dielectric constant; η is the ions mobility; e is the charge; n_0 is the ion density; t is time.

Let's investigate the aerosol development process, when the electrical charged particles are precipitating on the aerosol surface, which is effected by an electrostatic field.

Referring to [6]:

$$\frac{du}{dt} = -ku \qquad (2)$$

where k is the constant; u is the potential difference between development layer surface and developing electrode.

Let's integrate Eq. 2, taking into account the initial conditions:

$$u(t=0) = u_0 = v_i + v_э, \quad u(t = t_{np}) = u_{np} = v_2 + v_э. \qquad (3)$$

where $v_э$ is the potential of electrode; v_1, v_2 are the layers potentials at the starting and final moments of development. Therefore:

$$u = e^{\ln(v_1 + v_э) - kt}. \qquad (4)$$

Undertaking u values the development (speed) time could be determined as $u=v_2+v_э$, then

$$t_{np} = \frac{1}{k}\ln\frac{v_1+v_э}{v_2+v_э}. \qquad (5)$$

In the cases when the electrostatic surface density of the image is unique on the all surface of each element or Eq. 2 is equivalent to theequation

$$\frac{dE}{dt} = -kE, \qquad (6)$$

where E is the strength of the electrostatic field in the development area (zone).

Constant k could be determined by equation:

$$k = \frac{nq\mu}{(1 + l\varepsilon_{sl}/L_{sl})\varepsilon_0 \cdot 10^{-6}}, \qquad (7)$$

where n is the quantity of particles in the aerosols volume unit; q is the charge of a particle; μ is the mobility of particles; l is the distance between the development surface and developing electrode; L_{sl} is the thickness of the electro-photo-layer; ε_{sl}, ε_0 are the dielectric permittivities of electro-photo-layer and vacuum.

Let's integrate Eq. 6 and taking into account Eq.7 we can obtain:

$$E = E_0 e^{-\frac{nq\mu}{(1+l\varepsilon_{sl}/L_{sl})\varepsilon_0\cdot 10^{-6}}}, \qquad (8)$$

where E_0 is the initial value of the electric field, when t=0.

Quantity of particles of aerosol on the square unit during time t can be obtained:

$$N = n\mu\int_0^t E d\tau = n\mu E_0 \int_0^t e^{-\frac{nq\mu\tau}{(1+l\varepsilon_{sl}/L_{sl})\varepsilon_0\cdot 10^{-6}}} d\tau. \qquad (9)$$

In the case, when the charge of aerosol particles in the development area is constant, then the number of setting particles can be obtained:

$$N = \frac{E_0}{q_a}\left(1 + \frac{l\varepsilon_{sl}}{L_{sl}}\right)\varepsilon \cdot 10^{-6}\left[1 - e^{-\frac{nq_a\mu\tau}{(1+l\varepsilon_{sl}/L_{sl})\varepsilon_0\cdot 10^{-6}}}\right], \qquad (10)$$

where

$$q_a = 4\pi\varepsilon_0 E_a\left(1+2\frac{\varepsilon-1}{\varepsilon+2}\right) r^2 \frac{\eta e n_0 t_a}{4\varepsilon_0 + \eta e n_0 t_a}, \qquad (11)$$

where t_a is the charging time.

If the optical density of the developed image is proportional to the mass of particles, then taking into account Eq.10 and 11 we can obtain:

$$D_u = \frac{CmE_0(4\varepsilon_0 + \eta e n_0 t_a)}{4\pi\varepsilon_0 E_a\left(1+2\frac{\varepsilon-1}{\varepsilon+2}\right) r^2 \eta e n_0 t_a}\left(1+\frac{l\varepsilon_{sl}}{L_{sl}}\right)\varepsilon_0\cdot 10^{-6} \times$$

$$\times\left[1 - e^{-\frac{n\mu t_a \cdot 4\pi\varepsilon_0 E_a\left(1+2\frac{\varepsilon-1}{\varepsilon+2}\right) r^2 \mu e n_0 t}{(1+l\varepsilon_{sl}/L_{sl})\varepsilon_0\cdot 10^{-6}(4\varepsilon_0+\eta e n_0 t_a)}}\right], \qquad (12)$$

where C is the constant, obtained from an experiment; m is the mass of particle.

Dependence of charges in the optical density versus time, can be obtained as:

$$D_{um} = \frac{CmE_0\left(4\varepsilon_0 + \eta e n_0 t_a\right)}{4\pi\varepsilon_0 E_a\left(1 + 2\frac{\varepsilon - 1}{\varepsilon + 2}\right) r^2 \eta e n_0 t_a}\left(1 + \frac{l\varepsilon_{sl}}{L_{sl}}\right)\varepsilon_0 \cdot 10^{-6} \quad (13)$$

Conclusions

Usage of high frequency vibratory equipment for forming drops of liquid brings advantageous conditions for implementations of aerosolic development.

At the beginning the optical density of developing image is increasing and after some period of time the development process is slowing down.

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Aerozolinio ryškinimo proceso analizė

Reziumė

Aprašoma originali skysčio tiekimo ir dozavimo įrenginio konstrukcija, kurios veikimas paremtas aukštojo dažnio virpesių sužadinimu naudojant pjezoelementus. Pateikta aerozolinio ryškinimo stendo schema, išnagrinėtas ryškinimo procesas, nustatytos priklausomybės tarp aerozolio dalelių kiekio ir elektrinio lauko parametrų.

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