Influence of the Vibration Source Location on the Modes of Jet Disintegration in the Priller and on Monodispersity of the Finished Product

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Abstract – Influence of the vibration source location on the modes of liquid jets disintegration and obtaining monodisperse droplets and granules of the finished product is theoretically grounded and experimentally confirmed. The experiment was conducted on an experimental stand of industrial granulation equipment.

Keywords – forced perturbations, priller, regular hits, jet disintegration, monodispersity, satellite droplets.

I. Introduction

Currently the use of nitrogen-containing fertilizers is growing every year and further growth is expected according to the investigation conducted by BMI Research.

The most widespread methods of nitrogen fertilizers (ammonium nitrate, carbamide, NPK) production are prilling in towers and granulation (using fluidized bed granulator or drum granulator). Advantages and disadvantages of the listed methods are presented in [1].

Prilling method involves dispersing and cooling of the melt spherical droplets in a free fall and their crystallization in a counterflow of cooling air.

Modern prilling towers are equipped with prillers located at the top of the tower and melt droplets are produced by them (prillers).

The priller has a perforated bottom (bucket) and melt jets are outflowing from its holes and under influence of forced oscillations break up into droplets of a given size [2].

Forced jet disintegration into droplets is a very complex phenomenon, which has a variety of modes and depends on a number of internal and external factors [3].

The main interest of the contemporary scientists is drawn to the monodisperse mode of the jet disintegration into the main droplets without satellite droplets (small droplets) formation.

As one can see from the analysis of the nitrogen fertilizers production process stages, a great deal of fertilizer is lost with the dust emission of the granulated substance (satellite drops) which comes with the cooling air into the atmosphere [2]. In addition to the economic aspects associated with the product loss, this problem has an environmental one which is the pollution of air, surface and ground water; nitrites and nitrates accumulation in plants and reservoirs, which all results in a load on the ecosystem. Besides European Fertilizer Manufacturers Association stiffened the limit values for dust emissions of the product particles into the air.

The effect of forced oscillations on the modes of the liquid jet disintegration was investigated previously [4].

II. Challenge problem

Providing of continuous operation of the priller (granulator) technological units and maintaining stability of the operation parameters are important issues. Influence of hydrodynamic flows and local mechanical vibrations on the metal structure of the perforated bottom (bucket) lowers elastic properties of the material, which causes its plastic deformation, changing the shape of the discharge holes, and subsequent destruction of the bucket.

There occurs a problem of selecting optimal design parameters of the device for imposing forced oscillations on the melt, to increase duration of the equipment operation and improve quality of the finished product.

Analysis of the study results proved the efficiency of using the disc oscillator as a device for imposing forced oscillations. Disc is not firmly attached to the housing, which allows to reduce negative effect of local vibrations on the device. Oscillations are transmitted through a viscous melt (which under operating conditions can be considered as incompressible fluid) from the source to the bottom. Under this approach, the period of perforated bottom use increases significantly, since there are no local sources of vibration acting directly on the bucket.

As a result of previous theoretical studies of hydrodynamics of liquid jets outflowing from the holes in the bucket of a vibratory granulator, there was obtained a relation between parameters of the disc oscillator and change in the flow pressure by solving the Navier-Stokes system of equations for an axisymmetric liquid jet Eq. 1 [6]:

$$\begin{aligned} &2r\left(p\,Af\cos\left(2p\;f\,t\right)\right)^2\cdot\Psi+a_1\sin\left(w_1 t+c_1\right)= \\ &=p_{атм}-r\left(0.5\cdot 1/(p\,t\,r_o^2)\left(-2Q_{отв}+2p\,C_6 r_o^2-\right.\right. \\ &-4p\,C_8 r_s^2 r_o^2\ln r_o+2p\,C_8 r_s^2 r_o^2+p\,C_8 r_o^4- \\ &\left.\left.-4p\,C_3 z r_o^2+2p\,C_5 r_o^2+2p\,C_{10} r_o^2\right)+4n\,C_8\right) \end{aligned} \qquad (1)$$

III. Experimental research

Coefficient Ψ depends on the physical and chemical composition of the melt and the device internal design, including distance between the bottom and the source of vibrations. There occurs a problem in determining optimal location of the disc oscillator towards the bucket, to provide monodisperse disintegration of the jets into droplets. Theoretical study of the impulse transmission parameters is hampered by complex internal design of the device; therefore, to obtain more accurate solution, a series of experiments were performed using an experimental setup, shown in Fig. 1.

The experiment was carried out at parameters close to the parameters of a working industrial unit with a similar device design [2]:

- liquid flow in the device V=45 m^3/h;

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• diameter of the vibratory granulator housing D=0.5 m;
• the number of bucket holes, n = 5850 pcs;
• diameter of the discharge holes d_h=1.2 mm;
• vibration frequency f=375 Hz;
• distance between the bucket bottom and the disc oscillator (h) can be adjusted from 0 to 40mm.

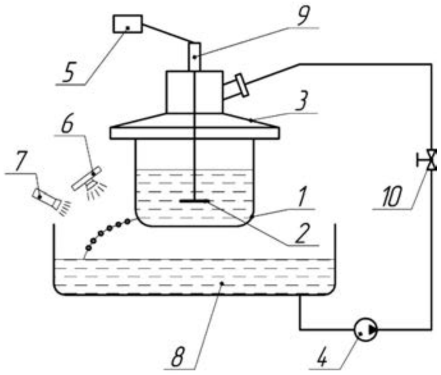
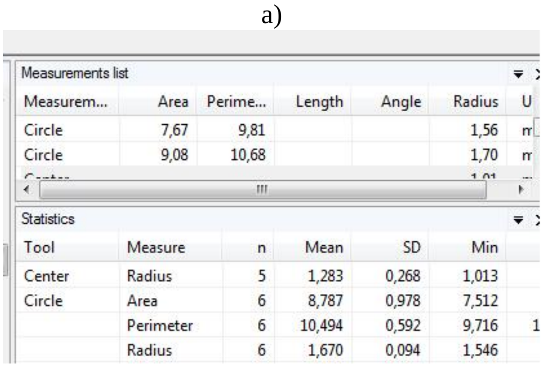


Fig. 1. Scheme of the experimental stand of the vibratory granulator: 1 – replaceable perforated bottom of the granulator; 2 – disc oscillator; 3 – housing; 4 – pump; 5 – vibratory generator; 6 – camera; 7 – stroboscope; 8 – buffer capacity; 9 – electromagnetic vibrator (actuator); 10 – control valve.

To obtain the most accurate data and reduce the overall level of error, a series of photographs was taken for each position of the disc oscillator. The images were analyzed using the method of detecting objects, searching for round figures using the specialized program (Fig. 2).

a)



Measurements list

Measurem...	Area	Perime...	Length	Angle	Radius	U
Circle	7,67	9,81			1,56	m
Circle	9,08	10,68			1,70	m

Statistics

Tool	Measure	n	Mean	SD	Min
Center	Radius	5	1,283	0,268	1,013
Circle	Area	6	8,787	0,978	7,512
	Perimeter	6	10,494	0,592	9,716
	Radius	6	1,670	0,094	1,546

b)

Fig.2 Determination of droplet sizes by a specialized program: a) photo processing; b) part of the list of measurements

IV. Results

There were constructed graphs of detailed analysis and suitable presentation (discussion) of the results (Fig. 3). In case if the disc oscillator is in contact with the bucket there is observed formation of satellite droplets simultaneously with the main disintegration of jets. It decreases the unit's capacity and negatively affects the environment as well as increases the costs of cleaning the worked-out coolant used to crystallize the melt. Formation of granules of regular spherical shape having maximal diameter occurs when the disc oscillator is placed 15 mm away from the perforated bottom of the vibratory granulator. In this position satellites are not formed and size of the main droplets increase. When the disc oscillator was placed at a distance of more than 30 mm, the number and dimensional scatter of satellite-droplet increased.

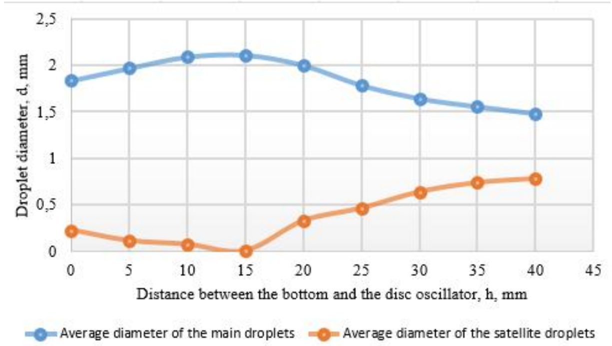


Fig. 3 Graphical dependence of the droplet diameter, formed after jet disintegration,on the distance between the bottom and the disc oscillator

Conclusion

As a result of the conducted studies, one determined influence of the location of forced oscillations source in the inner space of the priller (vibrating granulator) on the diameter of the target droplets and satellite droplets in the process of liquid jets disintegration. This study makes it possible to improve quality of the obtained products and minimize losses of the target product with the exhaust air by controlling position of the disc oscillator. Technology of transmission the oscillations through the liquid melt significantly increases the operation period of assembly parts and components of the vibratory granulator and it increases the general economic indicators of the production.

References

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