

04TCQ - QUALITY IMPROVEMENT OF GRANULAR NITROGEN FERTILIZER IN THE PRILLING PLANTS

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Abstract

Currently, the most common method of producing nitrogen fertilizer granules is a way to melt prilling towers, which produces more than 70% of the total volume of products. The method is characterized by prilling the melt dispersion of nitrogen fertilizer into droplets in the granulation tower, cooling and crystallization of solid granules in a free fall in the upstream of cold air.

The studies found that the process of disintegration of the jet into droplets can be stabilized by imposing on the melt stream forcing fluctuations close to the natural frequency decay. These fluctuations have a significant impact on the formation of droplets in the decay of the jet, reduce the length of disintegrated parts of the stream and sharply narrow fractional composition of the final products. Prospective design of dispersants is currently static and centrifugal dispersing device with superimposed vibrations.

Dispersants type RVG have reliable vibration system, which provides stable overlay fluctuations in the liquid jet flowing out of the holes of the perforated shell, regardless of changes in load on the dispersant on afloat. This allows the vibratory level measurement in the melt priller and thereby controls the degree of clogging and the exhaust velocity of the melt from the holes of the perforated shell. Researches were carried out in an industrial environment. The experimental results showed that the modified dispersant RVG with electromagnetic vibrator has enhanced monodispersity resultant product and reducing it in the dust-forming content of particles smaller than 1.0mm and more than 3.2 mm. The use of dispersants RVG with vibration unit helps to improve the quality of the nitrogen fertilizers, improve product quality and reduce emissions. Their operation can reduce the energy costs of production due to a significant decrease in the proportion of dust from exhaust air to the atmosphere.

Introduction

The world market for fertilizers in recent decades is developing rapidly, fueled by the growth of the world economy and agriculture. As a result, of less than 30 years, its volume increased almost 5 times and reached more than 70 billions dollars at the stable average values, growth rates of around 3% per year (Nitrogenous Fertilizers Market, 2014) Production of commodity forms of nitrogen fertilizer in two ways: by granulation and prilling. Granulation method is carried out by spraying and multiple layers of melt drops fertilizer on solids substandard product to form spherical pellets, and cooling them. As the main technological equipment fluidized bed is available (Firm "Mitsui

Tootsu" and "Toe Engineering"), vortex weighted layer apparatus (Artyukhov and Sklabinskyi, 2012), pan granulators (firm "Norsk Hydro"), drum granulators (firm "Kaltenbach Turing Process"). Also were developed methods of compression and granulation in spouted bed (Nakamura, 2007).

Currently, the most common method of producing nitrogen fertilizer granules is a way to melt prilling towers, which produces more than 70% of the total volume of products (Cheblakov et al., 2010). The method is characterized by prilling the melt dispersion of nitrogen fertilizer into droplets in the granulation tower, cooling and crystallization of solid granules in a free fall in the upstream of cold air.

Aims

The purpose of research: improving the uniformity of granules and reducing the amount of dust that blows from the tower with air.

Key tasks:

1. Substantiation relevance in the application of vibration technology for production of monodisperse droplets.
2. The study of hydrodynamics vibration dispersants.
3. Develop methods to reduce dust emissions from the air, which leaves the prilling tower.
4. Industrial tests of modified structures vibration dispersants.

Methodology

Studies were carried out on commercial plants producing ammonium nitrate and urea according to the procedure and the test program dispersants RVG.

Variable parameters:

- The rotation speed of the dispersant basket;
- Vibration frequency;
- The load on the melt nitrogen fertilizer.

Performance measures dispersant:

- Granulometric composition and temperature of the product;
- Strength of the granules;
- Rotation speed disperser, which regulates the diameter of torch the spraying granules in tower;
- The content of the dust fertilizer in the exhaust air from the tower.

To determine the size distribution of the resulting product granules are sampled at the outlet of the fluidized bed granulation tower and sieve analysis of samples carried out. Sampling should be carried out not earlier than 1.0 hours after the start of the granulator at steady state (under load). Subsequent sampling and analysis is carried out not less than 2 hours.

Grain size distribution of the product and the strength of the pellets were determined in accordance with regulations.

Modern prilling tower (fig. 1) represents an engineering structure up to 114 m in diameter and up to 16 m, depending on the performance, simple and reliable in operation (Chernyshev et al., 2009).

Results and discussion

For dispersion of melt nitrogen fertilizer used with different device form a perforated shell, generally having an axial symmetry. The operation of a centrifugal (rotary) granulator with a vibrator was carried out.

Rotation dispersant (priller) facilitates the distribution of granules on different trajectories. This improves the heat transfer conditions in the granulation tower, reduced fusion probability drops with formation of "double" prill.

Selecting areas of research related to the fact that the recent years, preference is mostly static dispersants with a corrugated or paraboloidal work surface and centrifugal (rotary) with cylindrical, conical and cupped perforated shells. This is due to their ease of manufacture and better indicators produce uniform liquid droplets, or pellets (fig. 2).

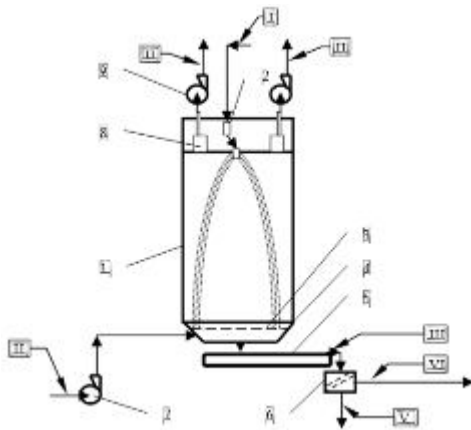


Fig. 1. The diagram for obtaining nitrogen fertilizer by prilling method: 1 -granulation tower; 2 – Separation of granulation (pressure tank, melt filter, dispersant); 3 - Cooler granules of the "fluidized bed"; 4 - cones; 5 - transporter; 6 - rumble; 7 pressure fan; 8 - air cleaning system; 9 - exhaust fans; streams: I- melt nitrogen fertilizer; II - the air; III - pellets of the tower; IV- pellet fractions of heading; V- substandard pellets for processing

A theoretical analysis of fluid motion hydrodynamics inside the perforated shell was carried out. In the result, toroid shape of the shell was chosen. The modification variety of dispersants and forms of their perforated membranes caused by the necessity of optimal distribution of the specific load on the cross section of the tower in order to intensify the heat transfer process. Fig. 3 shows the distribution of specific gravity irrigation over the cross section of the tower during operation of centrifugal dispersants with cylindrical, conical and toroid shell. As can be seen from the graphs, a better distribution have toroid shell. The rest of the shell does not allow achieve a uniform distribution of pellets over

the cross section of the tower. Have the worst performance dispersants with perforated cylindrical shell.

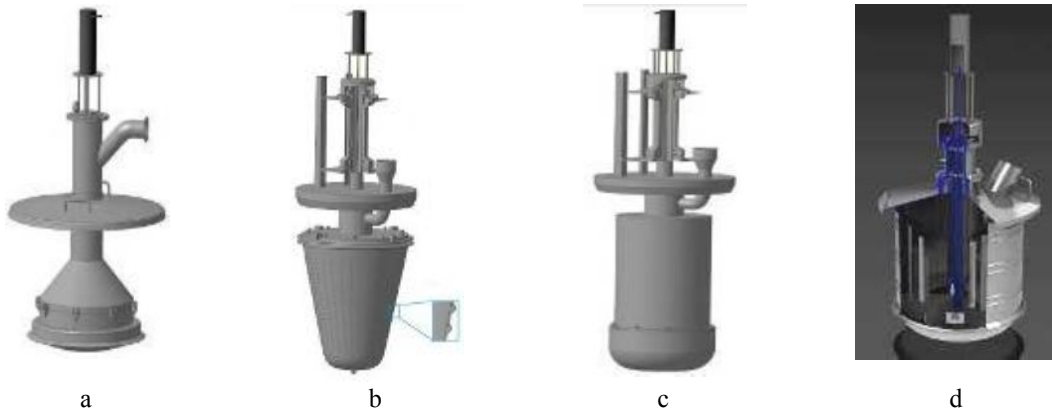


Fig. 2. Dispersants (priller) with an electromagnetic vibrator (development of Sumy State University): a - static dispersant; b - centrifugal dispersant with perforated conical shell; c - centrifugal dispersant with cupped perforated shell; d - rotating disperser with toroid shell perforated

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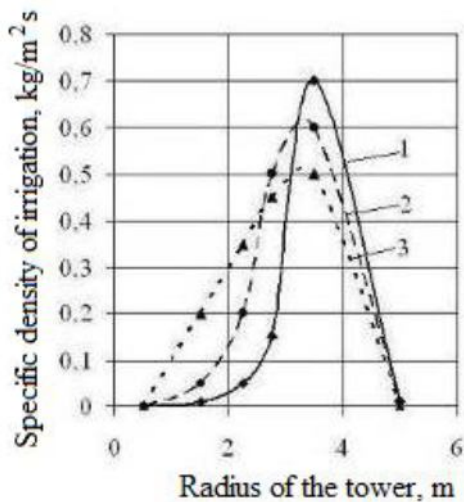


Fig. 3. Distribution of the specific density of irrigation on the cross section of the tower 1 - centrifugal melt disperser with perforated cylindrical shell; 2 - centrifugal melt disperser with perforated conical shell; 3 - melt rotary vibratory disperser of toroid perforated shell.

Studies and analysis of the results shows that the dispersant with a cylindrical, conical and hemispherical shells form can receive high-quality pellets. It is possible, if the choice of the form of the perforated shell liquid jets give the same initial velocity. In this case, it will be obtained a monodisperse spray of liquid into droplets. Analysis and calculation of the trajectory of the jet showed that the working surface of the perforated shell must perform profiled, which allows more evenly distribute the product over the cross section of the tower. For this it is necessary to know the path, speed, time and granules fall height. Determination of the maximum diameter of the melt spray dispersant and the trajectory of the granules are as necessary to optimize the thermal load of the granulation tower,

preventing adhesion of granules on the cone cooler fluidized bed or countertops mechanism discharging the product from the tower. This prevents crossing jets when installing multiple systems prilling. The research allowed optimizes the shape of the perforated shell rotary vibratory disperser RVG in accordance with the parameters of the granulation tower for various units of production of nitrogen fertilizers.

Monodisperse granules provide uniformity of their distribution and increases the effectiveness of fertilizer.

The studies found that the process of disintegration of the jet into droplets can be stabilized by imposing on the melt stream forcing fluctuations close to the natural frequency decay. These fluctuations have a significant impact on the formation of droplets in the decay of the jet, reduce the length of disintegrated parts of the stream and sharply narrow fractional composition of the final product. Prospective designs of dispersants are currently static and centrifugal dispersing device with superimposed vibrations.

Dispersants with vibrating generators allows obtain the granules of monodisperse structures only at calculated nominal load on the melt. At a deviation of nominal flow rate, decay ceases to be homogeneous. This leads to a significant deviation from the mean droplet size and the formation of satellite droplets, degrade the quality of the finished product.

If there are no vibrations, but the liquid jet breaks up into droplets, that there are significant deviations of the average diameter of the droplets from the calculated values. In addition, the formation of the jet between the droplets formed small droplets - satellites.

Laying on the jet external vibrations leads to the disappearance of the satellite droplets and formation of nearly monodisperse droplets (Sklabinskyi, Artyukhov et al., 2013; Sklabinskyi, Kononenko et al., 2013).

In the production of nitrogen fertilizers were applied three types of vibrators - pneumomechanical, hydroacoustic and electromagnetic.

Get a good quality product with the use of hydroacoustic vibrators is impossible, based on the design features of vibratory system. Vibration system of these dispersants is designed to operate on a strictly defined load on the melt (flow rate). Melt flow rate change entails rejection of the vibratory system. This leads to the spontaneous decay of the jets. Stable operation of hydroacoustic vibratory system to obtain monodispersed granules can load changes $\pm 15\%$ of the nominal.

Pneumatic vibrators also have significant drawbacks. To operate the vibrator resonator which it is tuned to a fixed value. This makes it impossible to regulate the size of the droplets when the load changes.

To increase the degree of monodispersity of pellets in a load change must be managed forcing frequency oscillations. Therefore, an object of study in this paper - a modified dispersant with electromagnetic vibrator.

Electromagnetic vibrator consists of a special generator frequency with the control unit and the vibration transducer (actuator). Special frequency generator designed to generate a predetermined signal frequency and amplitude of vibration on the converter, under the influence of the magnetic field results in reorientation of the lattice of the alloy material of the core, whereby the core changes its length. Vibration system can automatically control the frequency of vibration, depending on the load changes on the dispersant, change the average size of the granules obtained in the product range 0.25 mm, depending on climatic conditions and requirements for the fractional composition.

The results of particle size distribution of the product obtained in the various types of dispersants shown in Fig.4. Modified dispersant RVG with electromagnetic vibratory product will provide the following grain size distribution: the fraction of granules less than 1.0 mm - 0.02-0.2%, the fraction of granules 2.0-4.0 mm - more than 96%, while the share of granule fraction 2, 0-2.5 mm - no less than 88%, grain size of the main fraction - 2.1-2.5 mm. As the frequency of vibration dispersant provides a product with the main fraction of granules of 2.5-3.0 mm 65% while increasing the strength of the main fraction of granules.

When testing the modified dispersant RVG was a significant reduction in the content of ammonium nitrate dust in the air, which is discharged from the tower. This figure is at an axial fan from 22 to 48 mg / m³, with average values of 22 to 38 mg / m³. Disabling vibration system resulted in an increase of the dust in the air fertilizers 1.5.

The retrofit dispersant RVG allowed to produce a product with a content of 2.5-4.0 mm granule fraction of at least 75%, when the content of the fraction of particles less than 2.0 mm 0.8 to 3.0%.

Researches were carried out in an industrial environment. The experimental results showed that the modified dispersant RVG with electromagnetic vibrator has enhanced monodispersity resultant product and reducing it in the dust-forming content of particles smaller than 1.0mm and more than 3.2 mm. Comparative data on the content of the

mass fraction of granule size of less than 1.0 mm in the product that is discharged from the tower when using dispersants of different designs, are shown in fig. 5 (Artyukhov and Kononenko, 2013).

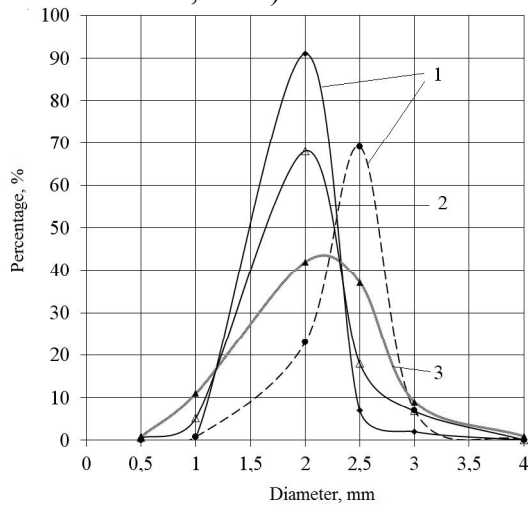


Fig. 4. Fractional composition of granules of ammonium nitrate: 1 - modified dispersant RVG with electromagnetic vibratory system frequency at 320Hz and 400 Hz; 2 - dispersant RVG with pneumatic vibratory system; 3 - static dispersant by Scientific Research Institute of chemical machinery design with acoustic vibratory.

Comparative data on the content of ammonium nitrate dust in the air that is discharged from the tower, with the various types of dispersants are shown in fig. 6 (Sklabinskyi et al., 2013).

Fig. 7 shows the strength characteristics of the comparative granules which are obtained using various granulating and various designs of vibrators. The strength of the granules using a granular design RVG (developer - Sumy State University) turned out higher. This is due to the greater monodispersity and better conditions for the heat transfer and the formation of granules.

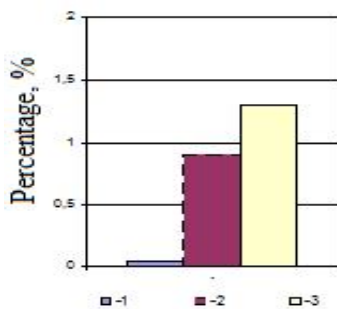


Fig. 5. Mass fraction of granules less than 1.0 mm in the final product: 1 - a modified dispersant RVG with electromagnetic vibratory system; 2 - dispersant RVG with pneumatic vibratory system; 3 - static dispersant by Scientific Research Institute of chemical machinery design with acoustic vibratory system.

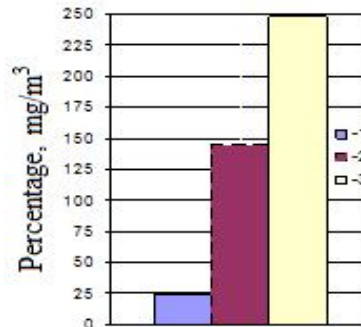


Fig. 6. The average content of ammonium nitrate dust in the exhaust air from the tower: 1 - modified dispersant RVG with electromagnetic vibratory system; 2 - dispersant RVG with pneumatic vibratory system; 3 - static dispersant by Scientific Research Institute of chemical machinery design with acoustic vibratory system.

Research has shown that the installation of the dispersant type RVG allows:

- vary the diameter of the spray from 3 mm to 7 mm;
- by increasing the pitch between the holes, reduce the probability of a droplets collision of the melt at the expiration of the holes;
- lower level (head) of the melt in the disperser, reduce the speed of its expiration and reduce the heat load on the tower.

Application of dispersant RVG also possible in single layer vortex granulator (SLVG). Currently developed design solutions that combine two methods of intensification of

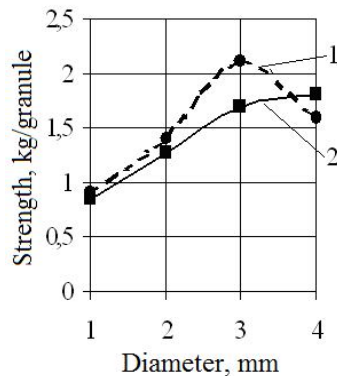


Fig. 7. Dependence of the strength of the granular diameter: 1 - modified dispersant RVG with electromagnetic vibratory system; 2 - static dispersant by Scientific Research Institute of chemical machinery design with an acoustic vibratory system.

heat and mass transfer processes - vibration effects and vortex flows (Artyukhov et al., 2008). Dispersants type RVG have reliable vibration system, which provides stable overlay fluctuations in the liquid jet flowing out of the holes of the perforated shell, regardless of changes in load on the dispersant on afloat. This allows the vibratory level measurement in the melt priller and thereby control the degree of clogging and the exhaust velocity of the melt from the holes of the perforated shell.

Similar results on the size distribution of the product were obtained on a modified disperse dispersant type RVG with electromagnetic vibratory producer of ammonium nitrate in tropical conditions in Cuba (fig. 7) and urea with foaming addition of hydro humates (fig. 9). With commercial operation of this equipment in a month consistently give the product the following granule-metric composition

(mass fraction, on the example of urea): granule size of less than 1.0 mm - 0.1-0.3%, 1.0-4.0 mm size granules - 99,7-99,9%; granules of 2.0-4.0 mm - 96,5-98,9%, granule size greater than 4.0 mm - are absent.

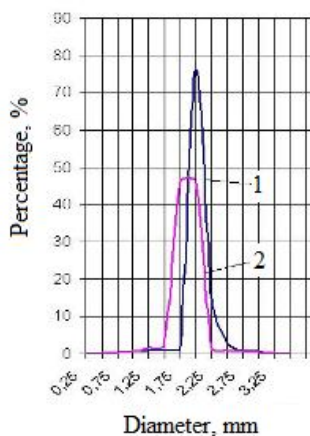


Fig. 8. Fractional composition of granules of ammonium nitrate produced in the dispersant-modified with an electromagnetic vibratory RVG in the production of ammonium nitrate in the tropical natural conditions

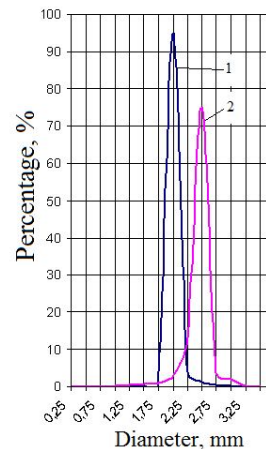


Fig.9. Fractional composition of urea granules obtained on a modified disperser RVG with electromagnetic vibratory in the production of fertilizers with hydrohumates.

Conclusions

The use of dispersants RVG with vibration unit helps to improve the quality of the nitrogen fertilizers, improve product quality and reduce emissions. Their operation can reduce the energy costs of production due to a significant decrease in the proportion of dust from exhaust air to the atmosphere.

Modified dispersant RVG has the following advantages over other granulator types:

1) High safety in operation; 2) Production of more competitive uniform granules; 3) Removal of product's sticking in towers; 4) Decrease of dust arising; 5) Increase of agro-technical value of fertilizers.

Modified dispersants RVG for ammonium nitrate and carbamide are produced in Sumy State University and operate on nitrogen fertilizer plants in Bulgaria, Estonia, Qatar, Cuba, Poland, Republic of Belarus, Russian Federation, Tajikistan, Uzbekistan, Ukraine and other countries.

Table 1 shows the comparison analysis of granulometric composition of the final product in the different types of dispersants.

Table 1. Comparison with world analogs by granulometric composition, %

Granule size, mm	Centrifugal dispersant of firm "Kreber" (Germany)	Acoustic dispersant designed by Scientific Research Institute of chemical machinery (Russia)	Dispersants RVG (Sumy State University)
1-4 mm	97-99	98-99	more than 99
2-4 mm	83-92	85-95	90-97
2-3 mm	75-90	80-90	more than 90
2-2,5 mm	40-50	45-65	more than 80
less than 1 mm	0,8-2,5	0,8-1,5	0,1-0,8

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