International Journal of Advanced Research and Development
www.multidisciplinaryjournal.net
ISSN: 2455-4030
Received: 10-03-2023, Accepted: 27-03-2023, Published: 11-04-2023
Volume 8, Issue 2, 2023, Page No. 22-26

Classification of granular particles and capture of dust/gas mixtures in a new type of device

Shirinova D B, Asgarova D E
Azerbaijan State Oil and Industry University, Baku, Azerbaijan

Abstract
Separation of ordinary sand and bentonite used in the preparation of drilling mud into fractions in a new type pneumatic multi-cascade cylindrical stepped classifier and cleaning of the dust-air mixture separated from the process was considered. The experiments were carried out for both dispersed particles at different values of the height of the steps, the amount of solid materials, the amount of air, the speed of the air flow, and the influence of the geometrical and technological parameters of the device on the separation process was studied. By adjusting these parameters, fractions of any size can be obtained. Depending on the size, density, shape, and chemical properties of the dispersed particles, it is possible to adjust the technological parameters of the process in the device. The dust-air mixture separated during the process is first sent to a dry dust collector, and then to a wet dust collector. Here, the air is cleaned of dust and fresh air is released into the atmosphere. In addition to the fractionation of dispersed particles, this environmentally friendly device can be used in catalytic processes, sorption processes, and filtering processes. The developed technological scheme also allows the placement of a shredder unit if necessary.

Keywords: classifier, fraction, dispersed particles, dust collector, stages, air flow rate

Introduction

Fractionation of granular materials is widely used in the enrichment of minerals, in the production of metal powders, in the processing of non-metallic raw materials, in oil and gas extraction, in the production of slag waste of metallurgical plants and thermal power stations, in the production of various brands of gravel, all dry products of the chemical industry, including fertilizers, catalysts, etc. In modern times, due to the increase in requirements for the quality of raw materials and intermediate products, and the increase in production volume, the involvement of low-quality raw materials in processing leads to an increase in the role of the separation processes of granular materials. At the same time, in order to reduce the impact of such dusty processes on the environment, the development of the technology for cleaning the dust-gas (air) mixtures separated during the classification of granular products in the same technological scheme is an urgent issue [1-5].

There are many production areas that are important for human life, and from these production areas, a large amount of different dust-gas mixtures are released into the environment. Thermal power stations, mining industry, fertilizer production, metallurgy and other heavy industrial plants, fractionation processes of granular materials, etc. are considered the main dust-gas mixture waste sources. Although there is a strict control of the permissible concentrations of dust in workplaces, various types of dust collection equipment is used, fines are applied to many enterprises or their work is suspended, this does not solve the problem. For this, the problem can be solved by developing new technologies and manufacturing new devices [1-5].

The classifier designed for the separation (classification) of powder materials is coaxially installed inside and outside the cylindrical body. Cylindrical parts are made in the form of a set of rings. In order to increase the efficiency of air dust removal in the shredding sorting complexes in the stone quarry and reduce the amount of dust emitted into the atmosphere, the author investigated the regularities of the process of dust separation in the centrifugal-inertial dry dust collector, which combines the principles of centrifugal-inertial separation of dust from the dust-gas mixture based on the mathematical model of aerosol dynamics with adequate experimental studies.

The idea of the work is that the design of the developed dust collector is based on the physical laws of the process of separation of dust-air mixtures, which determine the dynamics of the separation of solid particles from the air stream [7].

It is known that a large pressure drop in the system is necessary to obtain a high air velocity. This requires more energy, which increases operating costs. Although the initial cost of developing and installing high-speed air lines is low, the increased maintenance and operation costs require high operating costs throughout the life of the system.

The authors developed a low-speed ventilation system. The created system provides the airflow from the dust source to the dust collector at the same rate as the high-speed ventilation system.

The dust holding capacity of the low speed system is limited to particles smaller than 10 microns. Because of the absence of larger particles and the slower air velocity, duct friction in such a system is less than where the air changes direction. This allows the use of small radius bends or corner joints without excessive friction.

During the design process of the ventilation system, the sizes of the airflow ducts are selected taking into account the expected pressure loss in the system. Losses in the dust collector occur as a result of friction and pressure losses. As air velocity decreases, pressure losses caused by friction in ducts and joints decrease, which reduces operating energy costs.

Disadvantages of low-velocity ventilation systems include high capital costs and complex construction. In such systems, the ability to pass the required amount of air (m^3/h) through the ducts at a certain speed determines the diameter of the pipes, which is much larger than the ducts of the high-speed system. Since the channels cannot be located horizontally, a more expensive and difficult to install "sawtooth" design is used [8, 9].

Cylindrical parts are made in the form of a set of rings. The device has caps (covers) located on the rings of the inner body, rotating blades, and a feeding tube (for supplying the initial mixture) located between the rings of the outer and inner bodies, in the upper part of the conical part of the outer body. In the lower part of this body, there is a tube for separating the smallest (fine) particles. Under the rotating blades, there is a device for separating intermediate products. The separation process is controlled by reducing the aerodynamic resistance. The rings of the inner body are installed with a gap relative to the next cap [6].

Experimental part

In modern times, due to the increase in requirements for the quality of raw materials and intermediate products, and the increase in production volume, the involvement of low-quality raw materials in the processing leads to an increase in the role of the separation processes of granular materials [10].

Sieve, microscopic and sedimentation analysis methods are most often used for the experimental determination of the fraction composition in the crushing and classification of granular products. Sieve analysis gives satisfactory results only for fractions larger than 0.04 mm. For material fractions smaller than 0.04 mm, fraction composition is determined by sedimentation or centrifugation methods. These methods are based on different settling rates of particles of different sizes [11-14].

Material separation depends on the granulometric composition of the mixture such as fineness, shape, surface condition, density. The analysis of separation processes using sieves only gives information about characterization of the sizes of the separation products. There are deficiencies in the separation of granular products in production, as well as in the cleaning processes of dust and gas mixtures separated from the process at this time [15, 16].

The applied device-classifier was mainly used for the classification of dispersed particles. The working principle of this device is as follows:

- Flows of the transport agent (liquid or gas) and solid dispersed particles have a rectilinear direction;
- Presence of a heterogeneous system (solid material and compacting agent) in the vertical-ascending direction;
- The decrease of the velocity of the heterogeneous system in the direction of the flow;
- The possibility of changing the speed of the flow;
- The possibility of ensuring the deagglomeration of small dispersed particles in the construction in order to increase the efficiency of the separator-classifier;
- The possibility of stabilizing the flow of the heterogeneous system;
- To reduce the vorticity of the flow formed during the change in the consumption of separated materials in order to increase the separation capacity of the apparatus;
- The possibility of creating a filtering zone in the part where particles settle;
- Continuous withdrawal of the fractions and the observation of the sedimentation zone;
- Achieving continuous movement of the dispersed mixture to organize the optimal mode of separation of the polydisperse material.

Taking into account the disadvantages of existing air classifiers, a new type of ecologically-clean classifier was designed [17].

The equipment developed for the classification of granular materials in the rising gas flow divides the materials into fractions according to the density and size of the particles. This device can be used in oil refining, petrochemical, mining, metallurgy, construction industries and agriculture.

A pneumatic multi-cascade classifier consists of a cylindrical separation section divided into stages with an increasing diameter at each stage (the diameter of each subsequent stage is twice the diameter of the previous stage) and it is equipped with adjustable stages with a nozzle inserted at an angle of inclination from 0^0 to 90^0 to the horizontal surface. The body of the classifier is equipped with an additional wheel (coil) that increases its height.

The gradual increase in the diameters of the stages allows to a decrease in pressure, causes the separation of polydisperse substances and changes the velocity of the movement of particles. Large particles settle in the lower stages, small particles move to the upper stages.

Capacious nozzles installed on all stages allow to increase the particle flight distance and allow to adjust the separation of particles of the required size. The inclined nozzle (from 0^0 to 90^0) allows to change the direction of movement of the particles and the speed of the air flow.

By increasing the inclination of angle of the nozzle, the speed of the particles decreases and the vortex flow is not formed, which allows to increase the quality of separation of small particles from large particles. Large particles are captured from the lower stage of the classifier under the influence of gravity [18].

The advantages of the device include its work in a wide temperature and pressure range, the possibility of using it as a chemical reactor, as well as the simplicity of its design, high productivity, the possibility of separating granular particles into fractions of any size, and etc.

An additional nozzle and a wheel installed in the device allow to adjust the efficiency and productivity of the separation. Besides, the wheel also allows to change the height of the stage.

The change in the angle of the nozzles creates a eddy movement of the flow as it passes from one stage to another, and during such movement, with the change in the direction of the particles, the particles mixing performance is improved and the degree of separation is worsened. The angles of the nozzles are selected experimentally depending on the used (separated) material.

The gas-dust (solid particle) mixture enters the lower part of the classifier, where the device for dispersing conglomerates is installed. Here, conglomerates (combination of large particles with small particles) are dispersed due to the flow touching the inner and outer walls of the cylinders.

As the particles rise along the device, they repeatedly hit the walls of the device and change the direction of movement. 70-75% of conglomerates can be dissolved by changing the time of the flow in the device. After stabilization, the flow enters the conveying line of the classifier. A header with nozzles (45^0-$60^{0)}$ installed at the end of the conveyor directs the flow to the first stage of the classifier. The flow

consisting of gas and polydisperse material (dust) expands and enters the first stage.
A decrease in the flow rate creates good conditions for the particles to settle.
Particles with a small flight speed enter the sedimentation chamber and from there enter the receiver continuously. The particles cleant from the particles of this size enter the second stage, in which the above operations are repeated. Thus, n amount of fractions can be obtained in (n+1) stage.
The dust-gas mixture is given to the lower part of the separator-classifier (fig.). The two-phase flow passes through the stabilization part of the classifier and enters the first stage, where the speed of the flow decreases.
At this speed, dust particles that cannot fly settle in the anullar space of the first stage and are separated as the first fraction.

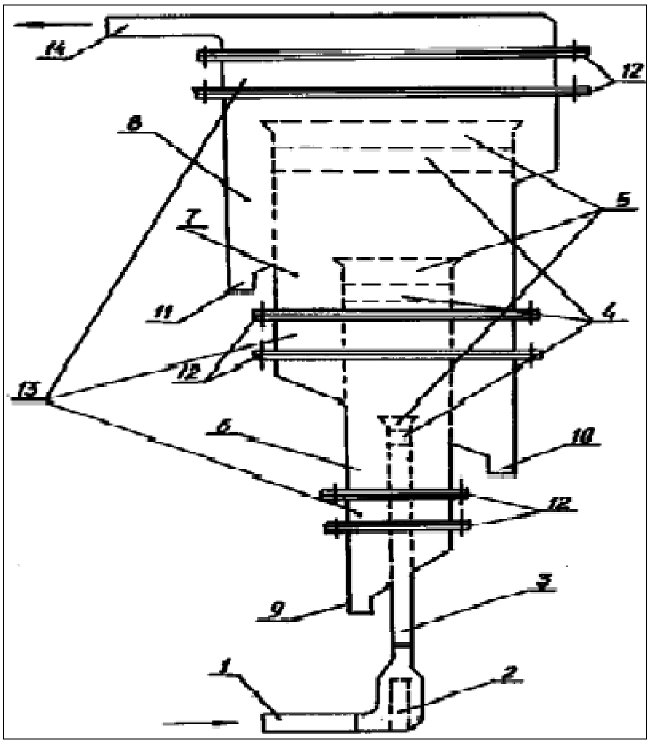

Fig 1

Fig. Overview of the classifier. 1-inlet; 2-deagglomeration equipment that separates the mixture; 3-conveying line (duct); 4-height of stages; 5-inclination angle of tip; 6,7,8-stages; 9,10,11- sedimentation zones; 12-flange connections; 13-wheel; 14-outlet.
The flow leaving the first stage enters the second stage. Dust particles that cannot fly at the speed of this stage settle in the annular space of the second stage, and the second fraction (dust) is separated from the outlet pipe of this stage.
In the third stage, the smallest solid particles (dust) that do not settle and are mixed with the air flow enter the dry collector. After the capture of small particles, the two-phase flow passes through the water layer and enters the wet collector, where the dust particles remaining in the flow are captured, and clean, but moist air is discharged from the outlet pipe of the collector. The air can be returned to the process. No additional equipment is needed for this.
The fact that the first stage is threaded allows to change the height of the first stage in the device [19, 20].
Nitrogen or other inert gases can be used as a liquefying agent during the separation of explosive dispersed particles (shavings, dust). Meantime, the gas is not released into the atmosphere, but is returned to the compressor and the inert gas circulates in a closed system.
For the experiment, bentonite used in the preparation of drilling mud and ordinary construction sand were taken and separated into fractions in the unit. The experiments were carried out with the same diameter of the classifier(the size of the diameter in each subsequent stage is twice the diameter of the previous stage) by changing the solid particles (sand and bentonite), supplied air and height of the first stage. The dependence of the fractionation process on the parameters is given in the tables.
Along with technological parameters, it is possible to obtain fractions of any size by changing the geometric parameters of the device.
During fractionation of both solids (sand and bentonite) in experiments I and II, although the amount of solids fed into the process and the amount of air were changed, the height of the steps was not changed. In the III experiment, the height of the I stage was increased, and the amount of solid matter to be fractionated and the supplied air were taken as in the I experiment.
From the comparison of the experiments, it can be seen that relatively large fractions (0.500-0.315 μm) are separated in stage I, fractions with size 0.200-0.160-100 μm are separated in stage II, and the main part of smaller fractions (0.63-0.50 μm) are separated in stage III. A very small part of 0.50 μm particles and particles smaller than 0.50 μm are captured in dry and wet dust collectors, and clean air is released into the atmosphere.
The above-mentioned size fraction separation for sand (table 1) in the first experiment is 74% in stage I, 83.9% in stage II, and 73% in stage III. In the second experiment, it is 79% in the stage I, 79.5% in the stage II, 72% in the stage III, and in the third experiment it is 78.5% in the stage I, 93% in the stage II, and 75.4% in the stage III.
The fractionation of bentonite (table 2) in the first experiment is 85% in the I stage, 82% in the II stage, 80.3% in the III stage. In the second experiment it is 78.2% in the I stage, 85.2% in the II stage, and 78% in the III stage. In the third experiment it is 82.3% in the I stage, 93.5% in the II stage, and 65.8% in the III stage.
During the separation of sand and bentonite into fractions of the same technological and geometric dimensions, we see the impact of the specific gravity of solids (specific gravity of sand 1300-1400 kg/m^3, specific gravity of bentonite 2500-2760 kg/m^3) on the separation process.
From the results obtained from the experiments, it appears that the appropriate fractions can be obtained by changing the height of the steps, the consumption of solids and air. The issue of capturing the dust (gas) released into the environment during the fractionation of solid particles has also been resolved. To do this, dry and wet collectors are used. Water was used as absorbent. The analysis showed that the amount of dust in the air discharged after the wet collector corresponds to the permissible concentration.
It is possible to clean (by absorption or adsorption) any dust-gas mixture separated simultaneously with the separation of granular particles into fractions in the processed unit.
As mentioned above, the developed technology can be applied in oil and gas extraction, petrochemistry, machine building, ore extraction and other industries as well as in the sorting and fractionation of cereals, as well as in environmental protection.

Analysis of results

The developed technology is an environment friendly process: the dust particles contained in the air stream leaving the process are first captured in a dry collector and then in an absorber (wet collector).

Experiments have shown that by changing technological parameters and geometric parameters, solid particles can be separated into fractions of any size. The impact of specific gravity and shape of powders (solid particles) on the separation process was determined. It is possible to clean (by absorption or adsorption) any dust-gas mixture separated simultaneously with the separation of granular particles into fractions in the processed unit.

As mentioned, the developed technology can be applied in oil and gas extraction, petrochemistry, machine building, ore extraction and other industries as well as in the sorting and fractionation of cereals, as well as in environmental protection.

Table 1: Dependence of the sand fractionation process on the technological parameters

Experiments №	Fractions	Amount, g/min.		Ratio, solid mat./gas, g/g	Amount of fractions, µm., %/g								The height of stages, mm	Speed in stages m/sec
		Solid material (sand)	Compacting agent (air)		0,500	0,315	0,200	0,160	0,100	0,063	0,050	>0,050	In the conveying line	3,14
1	initial	150	900,5	0,16657	3,87 5,8	14,86 22,3	23,07 34,6	17,53 26,3	16,1 24,15	10,77 16,16	9,67 14,51	4,13 6,18	85	0,12
	I	33,53	900,5	0,03723	9,54 3,2	64,12 21,5	18,64 6,15	1,49 0,5	2,45 0,82	2,63 0,88	1,13 0,38	-	25	0,216
	II	90,93	900,5	0,100097	2,85 2,6	5,2 4,8	26,7 24,35	28,6 25,8	24,36 22,15	5,6 5,15	6,19 5,63	0,5 0,45	45	0,008
	III	25,54	900,5	0,028362	-	-	-	-	4,62 1,18	39,66 10,13	33,28 8,5	22,44 5,73	210	3,37
2	initial	120,5	883,3	0,13642	6,93 8,35	19,40 23,38	25,2 30,36	23,63 28,47	11,35 13,68	6,95 8,37	4,61 5,56	1,93 2,33	85	0,115
	I	39,43	883,3	0,04464	21,2 8,35	57,95 22,85	15,62 6,16	1,9 0,75	0,38 0,15	2,1 0,82	0,88 0,35	-	25	0,023
	II	68,48	883,3	0,07753	-	0,72 0,53	35,34 24,20	39,6 27,12	18,03 12,35	3,1 2,12	2,18 1,56	0,88 0,6	45	0,01
	III	12,59	883,3	0,01425	-	-	-	4,76 0,60	9,44 1,18	43,1 5,43	20,0 3,65	13,7 1,73	210	3,67
3	initial	150	900,5	0,16657	4,2 6,3	16,2 24,3	21,76 32,65	16,5 24,75	15,48 23,2	10,6 15,9	10,23 15,35	5,03 7,55	85	0,125
	I	36,85	950,5	0,04092	17,1 6,3	61,33 22,6	9,36 3,45	6,4 2,36	5,08 1,87	0,73 0,27	-	-	65	0,025
	II	77,7	950,5	0,08628	-	2,19 1,7	37,58 29,2	28,81 22,39	25,93 20,15	2,93 2,28	2,55 1,98	-	45	0,0102
	III	35,45	950,5	0,039367	-	-	-	-	3,33 1,18	37,66 13,35	37,71 13,37	21,3 7,55	210	3,14

Table 2: Dependence of the bentonite fractionation process on the technological parameters

Experiments №	Fractions	Amount, g/min.		Ratio, solid mat./gas, g/g	Amount of fractions, µm., %/g								The height of stages, mm	Speed in stages m/sec
		Solid material (bentonite)	Compacting agent (air)		0,500	0,315	0,200	0,160	0,100	0,063	0,050	>0,050	In the conveying line	3,56
1	initial	150	900,5	0,16657	6,4 9,6	24,13 36,2	25,53 38,3	15,2 22,9	11,54 17,3	8,47 12,7	6,2 9,3	2,53 3,8	85	0,1217
	I	46,71	900,5	0,05187	15,41 7,2	69,36 32,4	6,10 2,85	4,1 1,9	2,78 1,3	1,27 0,6	0,98 0,46	-	25	0,025
	II	69,17	900,5	0,07681	3,47 2,4	5,49 3,8	48,1 33,25	28,26 19,55	5,27 3,65	4,69 3,25	3,8 2,63	0,92 0,64	45	0,0104
	III	34,12	900,5	0,03789	-	-	6,45 2,20	3,96 1,35	36,19 12,35	25,94 8,85	18,2 6,21	9,26 3,16	210	3,37
2	initial	120,5	883,3	0,1361	6,05 7,3	25,0 30,1	26,8 32,3	17,01 20,5	10,54 12,7	6,55 7,9	4,81 5,8	3,24 3,9	85	0,115
	I	44,24	883,3	0,05008	14,46 6,4	63,74 28,2	9,86 4,36	4,2 1,85	2,26 1,0	3,34 1,48	2,15 0,95	-	25	0,023
	II	58,52	883,3	0,06625	1,54 0,9	3,26 1,9	47,74 27,94	29,55 17,29	7,86 4,6	4,78 2,8	2,95 1,73	2,32 1,36	45	0,01
	III	17,74	883,3	0,02008	-	-	-	7,66 1,36	40,02 7,1	20,41 3,62	17,59 3,12	14,3 2,54	210	3,12
3	initial	150	950	0,16657	7,53 11,3	23,6 35,4	24,33 36,5	16,47 24,7	12,1 18,15	7,24 10,86	5,93 8,9	2,8 4,2	85	1,106
	I	56,77	950	0,06304	19,9	62,36	5,16	6,24	5,2	1,14	-	-	65	0,0217

					11,3	35,4	2,93	3,54	2,95	0,65				
	II	71,28	950	0,079116	-	-	47,1 33,57	27,68 19,73	18,7 13,33	3,9 2,78	2,62 1,87	-	45	0,009
	III	21,95	950	0,02437	-	-	-	6,52 1,43	8,53 1,87	33,8 7,42	32,02 7,03	19,13 4,2	210	3,56

References

1. Барский МД, Ревинцев ВИ, Соколеин ЮВ. Гравитационная классификация зернистых материалов М.: Недра, 1974, 172.
2. Родионов АИ. Защита биосферы от промышленных выбросов / А. И. Родионов, Ю. П.Кузнецов, Г. С. Соловьев. – Москва: Колос С, 2007, 392 с.
3. Юшин ВВ. Техника и технология защиты воздушной среды: учебное пособие для вузов / В. В. Юшин, В. М. Попов, П. П. Кукин. – Москва: Высш.шк., 2005, 391 с.
4. Ветошкин АГ. Основы процессов инженерной экологии. Теория, примеры, задачи: учебное пособие / А. Г. Ветошкин. – Санкт-Петербург: Лань, 2014, 512 с.
5. Кербалиев ГИ, Расулов СР. Гидродинамика и массоперенос в дисперсных средах. Монография. Санкт-Петербург: Химиздат, 2014, 568.
6. Пат. 1475734 B07B7/08 Классификатор порошкообразных материалов. Вирченко В. М.
7. Чистяков Я. В. Исследование и разработка пылеуловителей, обеспечивающих повышение эффективности очистки воздуха аспирационных систем дробильно-сортировочных комплексов карьеров Автореферат. Тула, 2012.
8. AB Cecala, AD O'Brien, J Schall, JF Colinet, WR Fox, RJ Franta, et al. Dust Control Handbook for Industrial Minerals Mining and Processing. Second edition. Report of Investigations – January, 2012.
9. Pat. İ 2021 0051 Az.R. Səpələnən materiallarin ozonlu mühitdə işlənməsi üsulu və qurğusu. Paşayev A.Mir C., Nizamov T.İ., Həzərxanov Ə.T., İsayev Ə.İ., Əliyev Ə.Ə., Quliyev F.K., Rzayev S.R.
10. Пат. 18154 C1 BY. 2014.04.30 Способ вихревой классификации дисперсных материалов на фракции в классификаторе. Лустенков В.М., Акулич А.В.
11. Пат. 205540 РФ. U1. 2021.07.20. Воздушно-шнековый сепаратор. Шепелёв С.Д., Ческидов М.В., Шепелёв А.С., Чирков Г.Н.
12. Дроздова О.И., Гребенникова В.А., Мансур Л.М., Шагарова А.А. Моделирование процесса классификации твердых сыпучих материалов. Энерго- и ресурсосбережение: Промышленность и транспорт. Волгоградский государственный технический университет, 2020, 18-23.
13. Кирсанов Виктор Александрович. Научные основы и принципы совершенствования процессов и аппаратов каскадной пневмоклассификации сыпучих материалов. Дисс. докт. техн. наук. Новочеркасск, 2005, 391 с.
14. Зиганшин МГ. Проектирование аппаратов пылегазоочистки / М. Г. Зиганшин, А. А. Колесник, А. М. Зиганшин.-Санкт-Петербург: Лань, 2014, 554 с.
15. Hailin D, Chusheng L, Yuemin Z, Lala Z. Influence of vibration mode on the screening process. Inter. Journal of Mining Science and Technology,2013:23(1):95-98.
16. Пономарев ВБ. Повышение эффективности процесса пневмоклассификации сыпучих материалов в каскадных аппаратах. Дисс.канд.техн.наук. Белград: БГТУ им. В.Г.Шухова, 2011, 144 с.
17. Ширинова ДБ, Агаджанов ХС. Процесс классификации мелкозернистого порошка карбида титана. Азербайджанский химический журнал. №2. Баку, 2000, 76-80.
18. Ширинова ДБ. Исследование процесса разделения кварцита на установке непрерывного действия. Азербайджанский химический журнал. №4. Баку, 2006, 172-174.
19. Ширинова ДБ. Разделение гранулированного суперфосфата в переходном процессе транспортировки. Проблемы современной науки и образования. № 8 (50), DOI: 10.20861/2304-2338-2016-50 Научно-методический журнал,Издательство «Проблемы науки», Москва, 2016, 58-60.
20. Ширинова ДБ. Гранулирование порошкообразного суперфосфата в условиях монодисперсного ретурного режима. European research № 8 (31), 2017. European research: innovation in science, education and technology. XXXI international scientific and practical conference. London. United kingdom 13-14 september, 2017, 25-26.