

**PROCESSES, EQUIPMENT AND APPARATUS
FOR THE FOOD INDUSTRY**

**INTENSIFICATION OF BULK MATERIAL MIXING IN NEW DESIGNS OF
DRUM, VIBRATORY AND CENTRIFUGAL MIXERS**

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Abstract: Problem of obtaining mixtures from bulk materials is of current interest for various industries, thus, analysis of original designs of drum, vibratory and centrifugal continuous mixers is an actual scientific task. Mixers developed in Kemerovo Technological Institute of Food Industry (University) for processing of bulk materials are easy to manufacture, provide highly effective mixing of ingredients with a broad range of physical-mechanical properties in thin vibroboiling and disperse layers, with the organization of various leading (bypass) and recirculation flows. Presented designs of mixers have small dimensions and low energy costs. They make good smoothing ability of complex input fluctuations possible using volume dosing. Mixing process time in them does not exceed a few minutes, different bulk compositions resulting in a good quality. Drum mixers under consideration, are characterized by little influence on material to be mixed, and may be used in technological schemes requiring the minimum damage to particles. They have also small dimensions. To obtain bulk compounds with a high mixing ratio it is appropriate to apply centrifugal continuous mixers, characterized by high efficiency at small size and low energy consumption. The examined designs combine mixing processes in thin layers of diluted and dispersed flows and they have a high degree of smoothing ability of input material flows. Mixing process intensification in the designs of continuous mixers is carried out by organization of internal and external recirculation of leading flows and separation of input flows into several parts and their subsequent multiple intersection.

Keywords: Drum mixer, vibratory mixer, centrifugal mixer, mixing intensification, bulk material, mixing quality, recirculating of material flows

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INTRODUCTION

Present requirements to the quality of mixtures are characterized by a considerable increase of physical - mechanical and flavoring properties of a final product. It is therefore advisable to develop new designs of continuous mixers (CMs), equipped with appropriate dosing devices. The authors present a brief description and the analysis of new CM constructions of drum, vibratory and centrifugal types developed in Kemerovo Technological Institute of Food Industry (University). They are designed to receive bulk compounds with different ratios of ingredients. For example, drum mixers allow the mixture to obtain a good quality with the ratio of its constituent components not exceeding 1:40, vibratory - 1:100, and centrifugal from 1:100 to 1:500 respectively. These units are characterized by high smoothing ability (inertia), low specific metal and energy costs, high intensity of mixing process, due to the organization of guided movement of thin material flows in conjunction with timing and recirculating. These units are suitable as the basic components for continuous mixing both separately and in any combinations thereof. For this, it is required when producing mixtures, e.g., with the ratio of ingredients

of 1:1000 to incorporate serially arranged continuous drum (mixing ratio 1:10) and vibratory (at the ratio of 1:100) mixers. The objective of the article is to acquaint the audience of scientists and engineers of food, chemical and allied industries with new constructions of drum, vibratory and centrifugal continuous mixers to produce bulk compounds with different ratios of ingredients.

OBJECTS OF STUDY

In the first stage, the construction of continuously operating drum mixers will be analyzed.

Continuous drum mixer manufactured by the Certificate of Authorship no. 1592024 [13] can be used for the production of bulk compositions in food, agricultural and other industries. This unit is the first in a series of drum mixers with Γ - shaped blades inside a rotor. First, the design and operation of this machine will be considered.

A drum mixer (Fig. 1) consists of frame 1, mixing drum 2, in which central shaft 4 is fixed in the centering supports 3. Blades 5 are located on the shaft. The frame is equipped with loading pipe 6, drive 7 and mechanism 8, allowing the drum angle to be changed.

Blades 5 in the cross-section are Γ -shaped. Mixing unit performance is as follows. Powdery components are put into the mixer by loading pipe 6. When drum 2 rotates, powdery components move down along Γ -shaped blades, simultaneously along its two guides. In addition to the separation of bulk material into two unequal flows on each blade, there takes place its circulation along the length of the drum. The movement of material occurs in the axial direction towards the discharge because of the presence of long blade sides in the mixing area. At this point, there is some mixture internal circulation, making a good smoothing ability of input components pulsations possible.

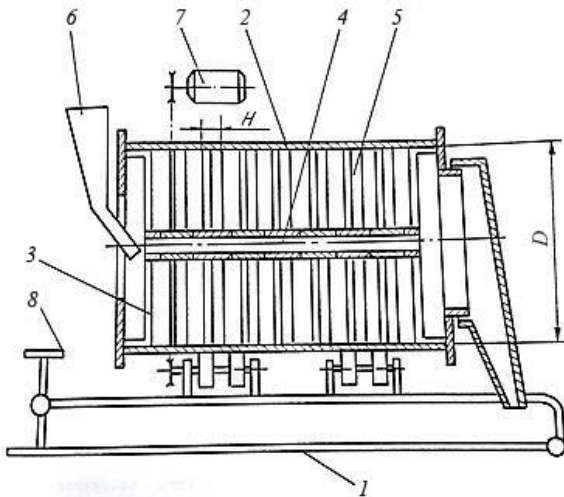


Fig. 1. Continuous drum mixer (Certificate of Authorship no.1592024): (1) frame, (2) drum, (3) centering supports, (4) shaft, (5) blades, (6) loading pipe, (7) drive, (8) tilting mechanism.

The analysis of this construction revealed inadequate longitudinal movement of the components to be mixed due to poor bulk material recirculating, resulting in a slight homogeneity of flows inside the drum. In addition, while stirring the particles having differences in density and dispersion are segregated. All this reduces the quality of the final mixture. To intensify the process of mixing and to increase the residence time of material particles in the unit, it is necessary to provide mixture recirculation. We propose to install Γ -shaped blades on the shaft rotating relative to each other at 360° , being located in a spiral or staggered manner (RF Patent 2508937 [7]). This leads to an increase in the mixture chaotic transverse movement, favors its overall homogeneity, and improves the quality of final product.

The mixer (Fig. 2) consists of drum 1, with fixed centering supports 2 therein, central shaft 3, which has Γ -shaped blades 4. Frame 5 is provided with loading 6 and discharge 7 pipes.

The drum mixer performance is as follows. Powdery ingredients enter the mixer by loading pipe 6. As the drum 1 rotates, they go down from the surfaces of Γ -shaped blades while moving simultaneously along the two drum guides 1. In addition to the separation of bulk material into two unequal flows on each blade, the circulation of mixed components takes place along the

length of drum. The main flow of material moves towards the discharge in the axial direction, big sides of the blades being on this side. Turning Γ -shaped blades relative to each other by 360° , we install them staggered (Fig. 3) or in a spiral manner (Fig. 4). When Γ -shaped blades are installed staggered the bulk material is divided into two flows, one of which moves to the previous blade, and overlaps the second flow from thereof. As a result, split flows repeatedly overlap each other, favorably affecting the overall quality of mixture homogeneity. When the blades are installed in a spiral manner, part of the components is gradually returning to the original point of its movement. This provides three-dimensional internal circulation and smoothing of input materials pulsations. The final mixture is put out from the mixer through discharge pipe 7.

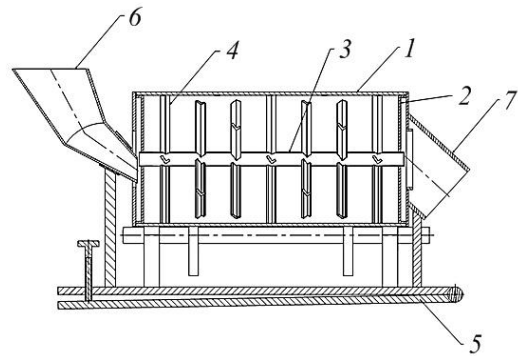


Fig. 2. Continuous drum mixer (Patent RF no. 2508937): (1) drum, (2) centering supports, (3) shaft, (4) Γ -shaped blades, (5) frame; (6) loading pipe; (7) discharge pipe.

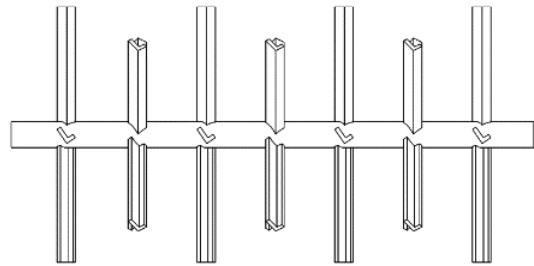


Fig. 3. Blades located staggered.

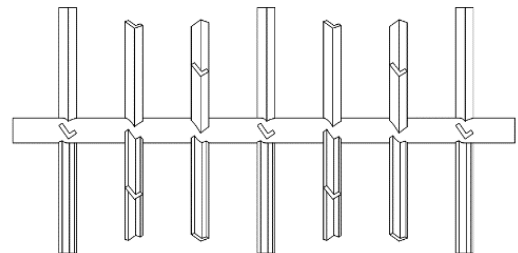


Fig. 4. Blades located in a spiral manner.

Thus, the multiple imposition of the flow of material inside the unit provides powder formulations of given quality. The proposed unit may operate in

batch mode too. In this case, the drum is installed horizontally. The circulation of flows along the length of the drum is retained therein as the axial flow generated by the difference in length and density is compensated by the counter flow obtained by the rolling of material at the angle of repose. Besides, the location of blades staggered increases the efficiency of material mixing with large fractions, while location of blades in a spiral manner provides material mixing with smaller fractions.

In the second stage, several constructions of continuous vibratory screw mixers that look like vertically mounted screws will be considered.

The first representative of this class is the mixer [9], schematically shown in Fig. 5. Components are put into the unit through pipe 1 to the upper chute of a perforated working body 2, where under the influence of screw vibrations, they form a helical layer, and are simultaneously sieved through perforations to underlying chutes and discharge pipe 5. One part of bulk material recirculates up through the chute. This flow is necessary to be reduced because it is influenced by local heterogeneity arising during mixture segregation and input flow fluctuations. The lower chute 6 performs the function of collecting, mixing, and guiding of final product to discharge pipe 5. The movable plate 4 is intended to recover pipe 5 when we start mixing before initiating stationary operating mode. After achieving optimal "boiling layer" height (10-50 mm) on the chutes, the plate is removed. Optimal height of "boiling" layer on the working body is achieved by the vibration parameters change, which affects the amount of the main and reverse flows, and their adjusting by plate 4 to the discharge pipe active section.

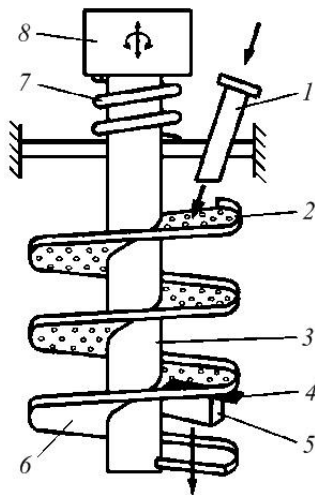


Fig. 5. In-line vertical screw vibratory CM with recirculation (Certificate of Authorship, USSR, no. 1674943): (1) loading pipe, (2) screw perforated tray, (3) bearing cylindrical column, (4) damper, (5) discharge pipe; (6) continuous spiral chute, (7) amortization connections, (8) vibrating drive.

Fig. 6 schematically shows an improved vibratory mixer with increased performance stability, protected by the USSR Certificate of Authorship, no.1793956

[10]. This stability is achieved in that the outer edge 7 of spiral chute is made inclined with alternating arrangement of perforated 8 and non-perforated 9 areas therein.

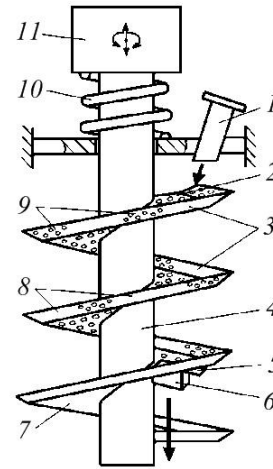


Fig. 6. In-line vertical screw vibratory CM with recirculation (Patent RF no.1793956): (1) loading pipe, (2) screw perforated chute, (3) outer inclined side, (4) bearing cylindrical column, (5) damper, (6) discharge pipe, (7) continuous screw chute, (8) non-perforated side areas, (9) perforated side areas, (10) amortization connections, (11) vibrating drive.

The ingredients are mixed simultaneously in the vibroboiling layer on the perforated working body in the unit and pour through the holes. The more is the humidity of components the less is their flow through the holes, causing a rise in the layer height on the chute. This phenomenon also occurs when the volume of input components entering through inlet 1 on to the upper chute of the working body increases. The growth of the height of bulk material layer leads to the increase of its width by tilting the external side 3. The holes 9 located on its surface start to work too.

Due to this, there occurs a flow increase through the chute perforations with layer height decreasing thereon. Conversely, while reducing the humidity of components or the volume of material entering the mixer, chute height and width also decrease, and the number of perforations, involved in the process decrease respectively. There arises a "feedback", which adjusts the layer height of the material distributed on mixer chutes. Because of this, the stability of mixing process increases. Alternation of perforated 9 and non-perforated (solid) 8 sections, does not allow material particles to slip the mixer from upper chutes directly to discharge pipe under control. This construction (Fig. 6), as compared with the previous one (Fig. 5) provides increased yield of the final product due to increased process stability.

However, we failed to overcome the tendency of discussed screw mixers to uneven chute loading with bulk material. This contributed to the beginning of the development of a new series of units, which lack this drawback. They have constant height of dispersed phase layer on chutes, high stability and good smoothing ability of input concentration fluctuations of

ingredients. Vibratory mixer [11] shown in Fig. 7 is one of the latest representatives of this group. Its working body consists of two parts: the main part 3 mounted on a vertical bearing support 1 from outside and the additional one 5 mounted therein. The outer part has a lifting in the direction of the movement of bulk material, and the internal one – a slope. The input components are put into screw chute 5. Under the influence of guided fluctuations, they roll over it to the hole in the pipe wall 1. As a result of ingredients sifting through perforations on the bottom row of chutes, there occurs prior compound homogenization. Further, they go to the lower continuous chute of the main working body, on which mixture as it moves upward to outlet 5, is graded up in vibroboiling layer. The availability of an additional working body 5, leads to an increase not only in the unit performance, but also in the mixture quality by increasing the length of working surface.

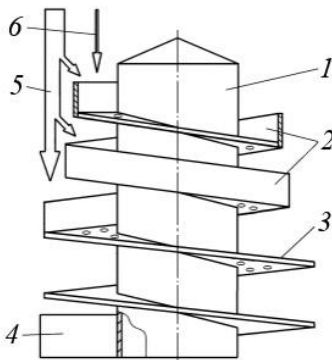


Fig. 8. Modernized additional working body: (1) cylinder, (2) narrow screw chute, (3) wide chutes, (4) guiding plate, (5) additional component, (6) key component.

To extend the range of ratios of mixed ingredients in the next invention a method of "serial dilution" is used. Thereby the width of upper chutes of additional working body [12] was reduced. On its narrow chutes 2 (Fig. 8) it is advisable to pre-mix ingredients, their share in the composition being small, or to add ingredients with the lowest consumption 6 and part of the bulk mass 5. Later semi-finished product is incorporated to the remaining part. The amount of dilutions depends on the initial ratio and mixing conditions. There are two of them in Fig. 8. In this case, the chutes 2 are made with the width proportional to the total consumption of components. Vibrating layer thickness on the chute is maintained in the range of 10-30 mm. Under the influence of force impulses, components are transported along the inclined side and mix therein. Some of the material moves through the perforations to the lower chute, then, the next part goes in. The process of the components "serial dilution" on the narrow chutes 2 is followed by their pre-mixing on wide chutes 3. The mixture moves through the hole (Fig. 7) on to the lower continuous chute of the outer spiral chute 4. Henceforth the process is similar to that of previous design.

In general, surface perforating of mixing elements is designed to smooth concentration fluctuations in

compounds, which takes place due to its movement on the chutes. This is important for discrete measuring out of components. With vibrating layer being created due to air leaks through the holes underneath the layer there is an increase in the rate of bulk materials transportation and reduction of required vibration parameters.

At the final stage, we will analyze the constructions of continuously operating centrifugal mixers, different from those of other types of mixers. They have higher performance at low energy and material costs and are characterized by high mixing process intensity that takes place in thin layers under the influence of centrifugal force. Basic requirements for CMs (providing quality mixing, good smoothing ability, high capacity, low metal and energy costs and others) are satisfied in these centrifugal mixers. A number of these mixers developed by us meet all the above requirements through organization of guided flow movement structure of material in the working chamber of the mixer.

A distinctive feature of the developed CMs is the presence of a rotor, made in the form of a hollow truncated cone, or a combination of cones, as well as in the form of special devices to create recirculation or leading flows.

The first representative of the centrifugal CMs [8], we have developed is shown in Fig. 9.

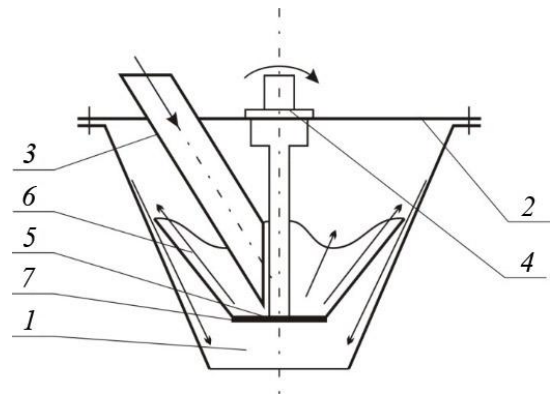


Fig. 9. Centrifugal mixer with wavy edged rotor (Patent RF no. 2361653): (1) casing, (2) cover, (3) loading pipe, (4) bearing connection, (5) shaft, (6) wavy edged rotor, (7) rotor disc.

The mixer operates as follows. Bulk materials are put into spinning rotor disk 7 through pipe 3. The weight of bulk components, under the influence of centrifugal force is distributed uniformly over disc 7, moving to the inner surface of cone 6. This results in a thin-layer movement of free-flowing components and facilitates partial mixing of materials. While "spreading" on the surface of cone 6, bulk material moves to its upper wavy edge, the configuration of which facilitates the creation of an additional mixing effect in crossed material flows because the total annular material flow is poured from conical surface at different time intervals. Thereafter, dry bulk material flow is divided into several parts, overlapping each other subsequently in the annular space between the casing and the rotor of mixer. Thus, the unit's

smoothing ability and mixing intensity are greatly enhanced without additional energy consumption. The final mixture goes to the inner surface of casing 1 and is discharged from the unit.

Its disadvantage is low residence time of particles in the unit. This does not allow high-quality mixture to be obtained at the ratio of components to be mixed more than 1:80. To solve the problem we installed an extender on the shaft (below the rotor) in the form of perforated double stroke screw located in cylindrical pipe, which is connected with the outlet of conical casing (Fig. 2). This increases the residence time of material in the unit and, consequently, increases mixer smoothing ability that makes mixture components batch dosing possible.

Centrifugal - screw mixer performance (Fig. 10) [2] is as follows. Free-flowing materials are put into the spinning rotor disk 7 through pipe 3. Bulk components, under the influence of centrifugal force are distributed uniformly over disc 7, moving to the inner surface of cone 6. Thus, the thin-layer movement of bulk components takes place facilitating partial material mixing. While "spreading" on the surface of cone 6, bulk material moves to its upper wavy edge, the configuration of which facilitates the creation of an additional mixing effect in crossed material flows because the total annular material flow is poured from the conical surface at different time intervals. The material moves along the inner surface of the casing 1 to the outlet pipe 9 and goes to perforated screw 9. Owing to the fact that when shaft rotates, screw chutes lift the material upwards, the latter is recirculated. Part of the material pours through screw perforations and a gap between the screw and the pipe down, and it goes out from the mixer as the final mixture form. The proposed constructive solution allows increasing material residence time in the mixer. The smoothing ability of the unit increases too. In other words, mixing process in the proposed construction takes place in two stages and makes batch dosing of components possible.

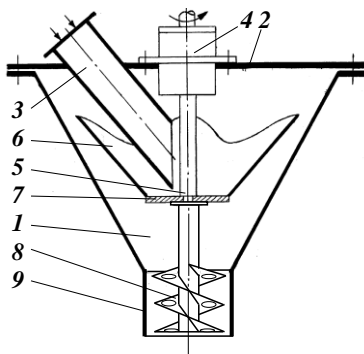


Fig. 10. Centrifugal-screw mixer (Patent RF no. 148608): (1) conical casing, (2) cover, (3) loading pipe, (4) bearing connection, (5) shaft, (6) cone, (7) disc, (8) perforated screw chute, (9) pipe.

Besides we increase residence time of material in the rotor and, consequently, improve the quality of final product by the engineering solution in accordance with RF patent no. 2496561 [1]. On the inner surface of cone there must be installed angle-like baffles

located at different angles to the axis of rotation, on the outer one there must be fixed a scattering disk, and on the inner surface of the mixer casing - perforated guides. Due to the different lengths and angles of the angle-like guides, bulk material trajectories are repeatedly intersected, thereby increasing the residence time in the unit, and its smoothing ability.

The mixer, shown in Fig. 11 operates as follows. Bulk materials are put onto the base of rotating cone 8 through pipe 3. Under the influence of centrifugal forces bulk particles move with acceleration from the central part to the periphery evenly spreading along its inner surface. Thus, the thickness of layer at the periphery becomes smaller. This is due to the increase of the surface of particle distribution. Material flows are reflected from angle-like baffles 9, which vary in length and angle of slope. This design promotes formation of an additional mixing effect in crossed material flows as the annular flow of material is divided into pieces, overlapping each other subsequently. Thereby greatly increases smoothing ability of the unit and intensity of mixing process without additional energy consumption. Then, mixture, dropping through upper base of hollow truncated cone 8 is put into perforated guides 10, and divided into two parts, one of which is poured through the holes to the bottom of the conical base of casing 6, and the other part is supplied to scattering disc 11. Material particles are cast away from the scattering disc to the walls of casing 1. They are intersected with the flow which has passed through the holes in the perforated guides 10, creating additional mixing thereby. The final mixture is discharged from the unit through pipe 7.

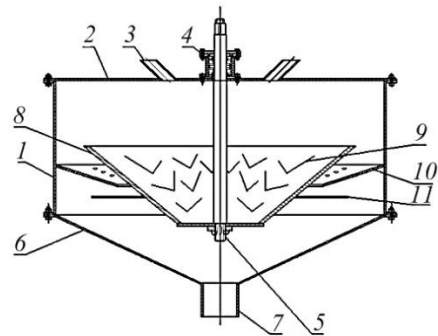


Fig. 11. Centrifugal mixer with angle-like baffles (Patent RF no. 2496561): (1) casing, (2) cover, (3) loading pipes, (4) bearing connection, (5) shaft, (6) conical bottom, (7) discharge pipe, (8) rotor, (9) angle-like baffles, (10) perforated guides, (11) scattering disc.

In addition, the intensification of mixing process can also be achieved through the installation of a flexible screw on the outside of the mixer (RF patent no. 2523576 [7]). This provides the external recirculation of material flow back into the working area, where it is mixed with the original components in the unit, the quality of resulting mixture being improved.

Centrifugal flexible screw mixer (Fig. 12) performance is as follows. Bulk components are fed through pipe 3 onto rotor base 8. Under the influence

of centrifugal force, bulk material is evenly distributed across the base of rotor disc 8 from the center to the periphery, then, it moves to and along the cone surface upwards. The main annular material flow moves over cone surface, getting into the space between mixer casing and rotor. Material on the elliptical bottom 4 is divided into two parts, one of which (final mixture) is discharged from the unit through discharge pipe 9 by means of agitators 7. Another one goes to flexible screw 10, along which it rises and goes again to the basis of rotating rotor 8, where it is mixed with the main material flow entering through loading pipe 3. This results in the external flow recirculation and homogenization of material, the quality of the final mixture being increased.

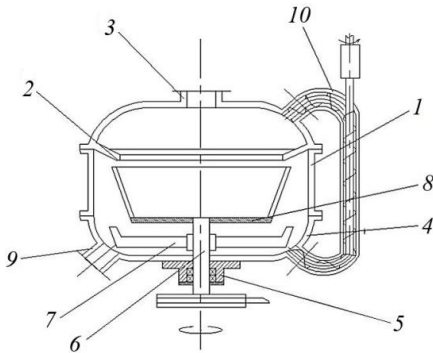


Fig. 12. Centrifugal mixer (Patent RF no. 2523576): (1) casing, (2) cover, (3) loading pipe, (4) elliptical bottom, (5) bearing connection, (6) shaft, (7) agitators, (8) rotor; (9) discharge pipe, (10) flexible screw.

A common shortcoming of centrifugal mixers is the fact that under the influence of centrifugal force finely dispersed components in mixture move upwards, leading to partial stratification (segregation).

To eliminate this drawback and to increase the intensity of mixing process, we propose to install a guiding diffuser in the mixer [3], which creates the predetermined movement of dusty flows. Besides, this engineering solution allows us to eliminate stagnant areas in the rotor center, increase the duration of material particles movement inside the unit, and significantly reduce the degree of segregation.

Fig. 13 is a perspective view of the centrifugal mixer with a guide diffuser, whose operation is as follows. Bulk components go to the rotating rotor disk base 9 through loading pipe 3 and uniformly spread out thereon, under the influence of centrifugal force. Hereinafter, the particles move upwards along the surface of thin-walled hollow truncated cone 10. At the beginning of the movement of components along the cone 10 superfine particles start to go to dusty area, and the main material flow continues to move along its surface. After superfine particles have risen upwards, they go round the guide diffuser surface 4 and urge towards the center of rotor, where they are mixed with new material flow moving along the rotating cone surface 10. Having reached its upper edge, under the influence of centrifugal force, the final mixture is discharged into the space between rotor and casing 1,

getting to the bottom of mixer 5. The final mixture is removed from the unit by unloading blades 8 through discharge pipe 6.

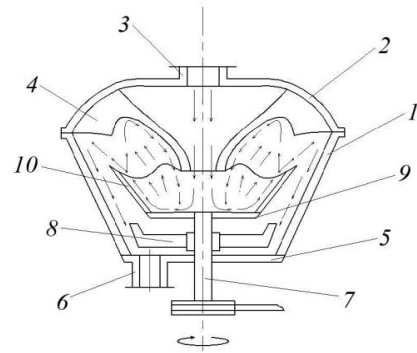


Fig. 13. Centrifugal mixer with guiding diffuser: (1) casing, (2) cover, (3) loading pipe, (4) guiding diffuser, (5) mixer bottom, (6) discharge pipe, (7) shaft, (8) blades, (9) rotor disc, (10) cone.

The above mentioned construction of one-cone centrifugal mixers allow us to obtain predetermined quality at the mixture ratio of mixed components in the range from 1:80 to 1:200, which is slightly reducing their application. When preparing mixtures with proportions of ingredients of about 1:400 it is necessary to increase significantly residence time in mixer working area while increasing unit smoothing ability. To achieve this goal, we propose to install additional cones, and to fix reflectors in the form of one-size individual elements of the torus on their inner surface, the latter being located on different cones staggered with respect to each other. When material passes over all the cone surfaces, residence time of particles in the unit increases. Besides, it increases because of mixture recirculation at the middle and outer cones, which beneficially affects the quality of finished product.

Fig. 14 is a perspective view of centrifugal continuous mixer [4] and its conical rotor isometric projection. The mixer operates as follows. Mixed materials go on to the inner cone base 8 through the loading pipe 3. Cone angles of slope and guide height are increased from the center to the periphery of rotor. Bulk materials under the influence of centrifugal force move from the center to the periphery of disk, and then— to cone surface 8. After that, they pass to the middle cone surface 9, where the flow is partially split, one part of which is moved to reflectors 11 of the middle cone 9, and to its base, resulting in bulk materials reverse recirculation and higher accumulating capacity of the unit. Under the influence of centrifugal force, the other part of material goes to the outer cone 10, where the flow of material is similarly divided into parts, one of which is cast away to casing 1, and the other, thanks to deflector elements - to cone base 10. By mounting these reflectors staggered at the middle and outer cones 9 and 10 partial recirculation of material flow is generated. The final mixture is poured into the conical area of casing 1, and is then put out from there through discharge pipe 4 with blades 12.

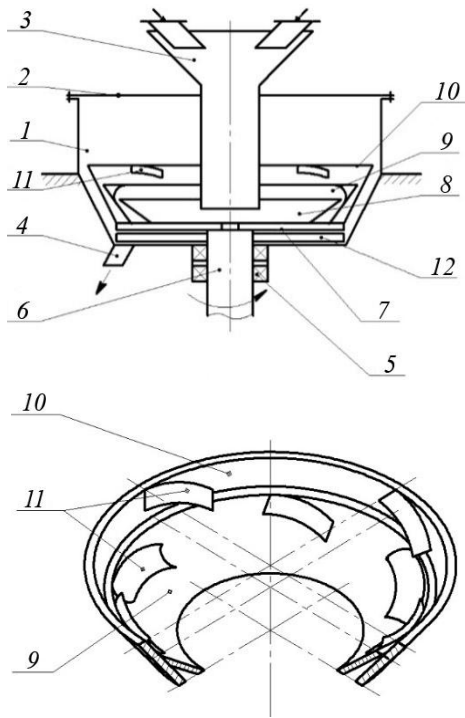


Fig. 14. Centrifugal mixer (Patent RF no. 2455058): (1) casing, (2) cover, (3) loading pipes, (4) discharge pipe, (5) bearing connection, (6) shaft, (7) rotor disc, (8) inner cone, (9) middle cone, (10) outer cone, (11) torus reflectors, (12) discharge agitators

When the influence on processed materials containing conglomerates is not intensive enough it is difficult to obtain a final product of high quality. Therefore, to increase the quality of final mixture, dispersing capacity of the mixer must be increased.

We propose to intensify the process of mixing and dispersing of dry bulk materials containing conglomerates by their multiple destruction and dispersion with conical blades installed on the rotor. This constructive solution makes mixing in thin dispersed layers of equal thickness possible, ensuring uniform loading in rotor cones, and mixing at the level of individual particles and micro-volumes.

A general view of a centrifugal mixer dispersant [5] and its isometric view of the rotor are shown in Fig. 15.

The mixer operates as follows. The input bulk materials go through loading pipe 3 to the rotating conical blade containing four agitators 11, destroying conglomerates of bulk components. Thereafter, loosened and crushed mixture constituents under the influence of centrifugal force move along the inner surface of cone 8. Mixed components move along the surface of the middle cone 9. Having reached its periphery, material flows and the remaining conglomerates go to the surface of dispersing blades 12, where additional destruction and mixing of bulk materials take place. Then, grinded and mixed components go to the surface of outer cone 10, where the same process of mixing and dispersing is repeated. Under the influence of centrifugal force, mixture from cone 10 goes to the lower part of casing 1, and is removed by agitators 13 through discharge pipe 4.

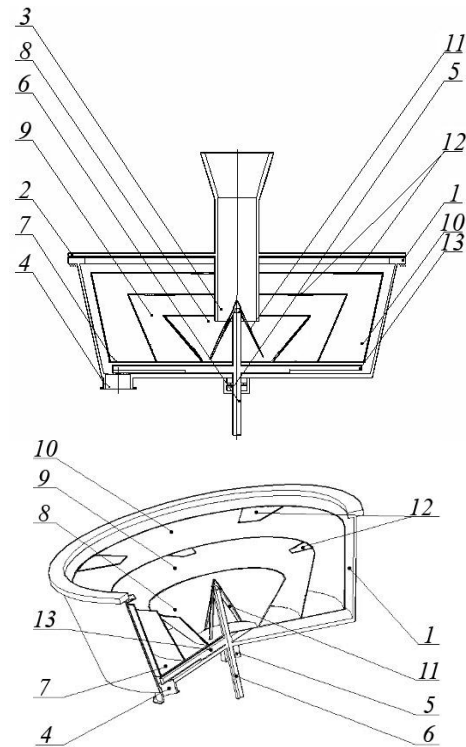


Fig. 15. Centrifugal diffuser mixer (Patent RF no. 2464078): (1) casing, (2) cover, (3) loading pipes, (4) discharge pipe, (5) bearing connection, (6) shaft, (7) rotor disc, (8) inner cone, (9) middle cone, (10) outer cone, (11) conical blade, (12) dispersing agitators, (13) discharge agitators.

CONCLUSIONS

1. Drum mixers under consideration are characterized by small influence on mixed material. Therefore, they should be used in the technological schemes, requiring the least damage to particles. They provide the maximum degree of smoothing of input flow fluctuations as compared with the vibratory and centrifugal mixers. These units can be used together with vibratory or centrifugal mixers to obtain mixtures with a large ratio of mixed ingredients.

2. CMs have the greatest practical importance among the constructions of vertical lift screw vibratory mixers presented in Fig. 7 and 8. They are easy to manufacture, can effectively mix ingredients with a wide range of physical-mechanical characteristics in a thin vibroboiling layer and have small dimensions.

3. To obtain bulk compounds with a large mixing ratio it is expedient to use continuous centrifugal mixers, characterized by overall high efficiency at low dimensions and energy consumption costs. CM constructions under consideration combine mixing processes in thin layers of diluted and dispersed flows and have a high degree of error smoothing in the input material flows.

4. The intensification of mixing process in the considered CM structures is carried out by the organization of internal and external recirculation of leading flows as well as the separation of input flows into several parts with their subsequent multiple intersection.

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