

INFORMATION

CLASSIFICATION OF ROTARY MIXERS WITH AN ADJUSTABLE WORKING SURFACE (REVIEW OF PATENTS)

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A classification of rotary mixers having a transformable working surface used in chemical production equipment is presented. Leading designs of specified rotary mixers developed by inventors of the leading countries over the last half fifty years are considered.

Keywords: chemical equipment, rotor mixer, transformable working surface, classification, designs.

Mechanical mixing, representing a common type of liquid mixing in chemical technology, is implemented by means of technological and auxiliary agitation equipment [1–3].

Among the various types of mixers, rotary mixers are most in demand, capable of changing the intensity and efficiency of the mixing process achieved by controlling both the variable- and periodically-repeating rotation rate (Pat. No. UA30409U and No. UA50139U). This appears to be typical for mixers having a fixed (invariant) working surface, in contrast to the developed designs of rotary mixers based on an adjustable working surface, characterised by wider technological capabilities.

According to the performed design analysis, adjustable working surface rotary mixers applied in chemical plant equipment can be classified as follows (Fig. 1).

Fixed and resizable mixers are distinguished **according to the adjustability of mixer size**.

The described mixer (Pat. No. UA60259U) is made of two disks fixed on the shaft, comprising holes for the passage of the processed medium and interconnected by rigid longitudinal elements. A solid disk is mounted on the shaft between the disks with holes (Fig. 2). In the upper and lower parts of the vessel, the circulation intensity of the processed medium is regulated by a change in the position of the solid disk.

The Pat. No. UA60260U mixer is made of two shaft-fixed assemblies (in the form of disks or blades) interconnected by telescopic longitudinal elements. One of the assemblies is mounted on a shaft, providing the possibility to change its position along the shaft length. By adjusting the distance between the assemblies, it is possible to vary the volume of the processed medium, in which the longitudinal elements of the mixer actively operate.

A static comb is affixed to the body of the Pat. No. UA60780U mixing vessel, comprising a vertical shaft with a comb mixer. The plates of the comb mixer are positioned such as to permit passage through the slots formed by the plates of the static comb, with each plate being mounted in rotation around its longitudinal axis. The necessary hydrodynamics is provided in the vessel by means of the individual rotation of each plate of the static comb.

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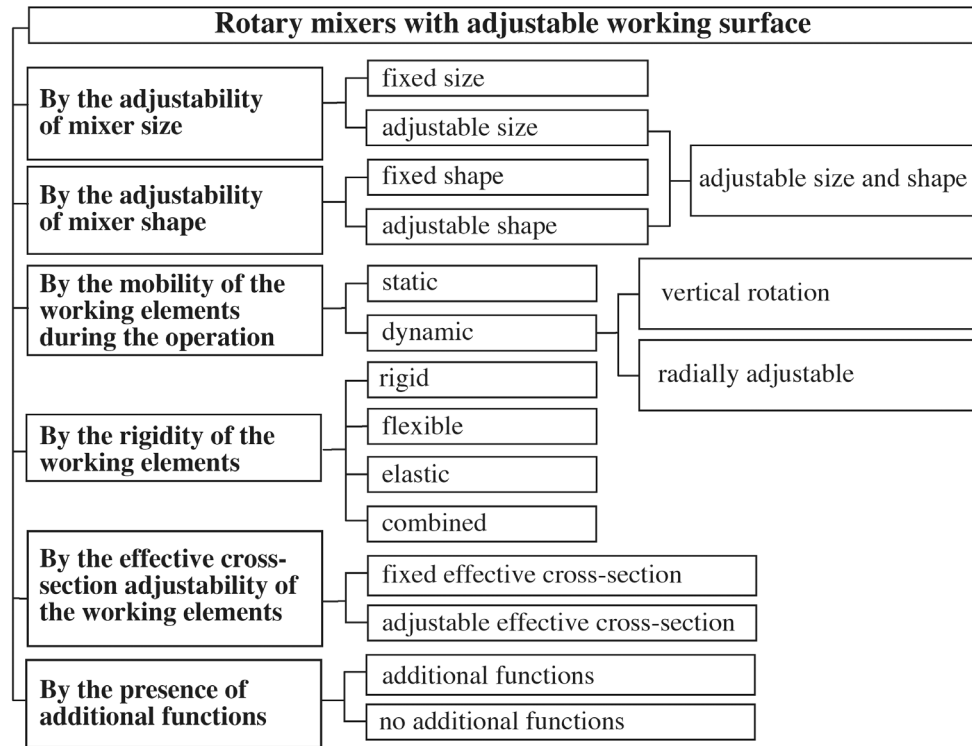


Fig. 1. Classification of rotary mixers having adjustable shape and/or size.

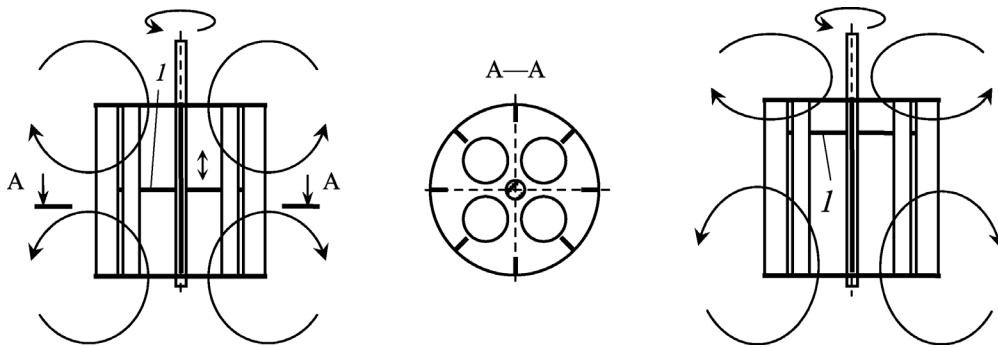


Fig. 2. Operational scheme of the Pat. No. UA60259U mixer at various positions of the middle solid disk *I*.

On the vertical shaft of the Pat. No. UA61281U sheet mixer, two sheet blades are fixed on the same plane. Over its thickness, each of the blades is made of two parts mounted so as to support relative displacement along the vertical shaft and fixation in the required position. With a relative shift of the parts of each blade, the volume of liquid, on which the agitator actively impinges, changes.

On the vertical shaft of the Pat. No. UA65292U sheet mixer, two blades are mounted (in the same plane) in the form of sheets with holes. Over its thickness, each blade is made of two parts mounted with a gap relative to each other. The necessary hydrodynamics of the liquid being mixed in the vessel is ensured by changing the size and shape of the gaps between the parts of the corresponding blade (Fig. 3).

The Pat. No. UA68866U mixing device is distinguished by a stationary agitator mounted in the lower part of the vertical shaft, as well as an additional agitator having positive buoyancy (fixed on the sleeve). The sleeve

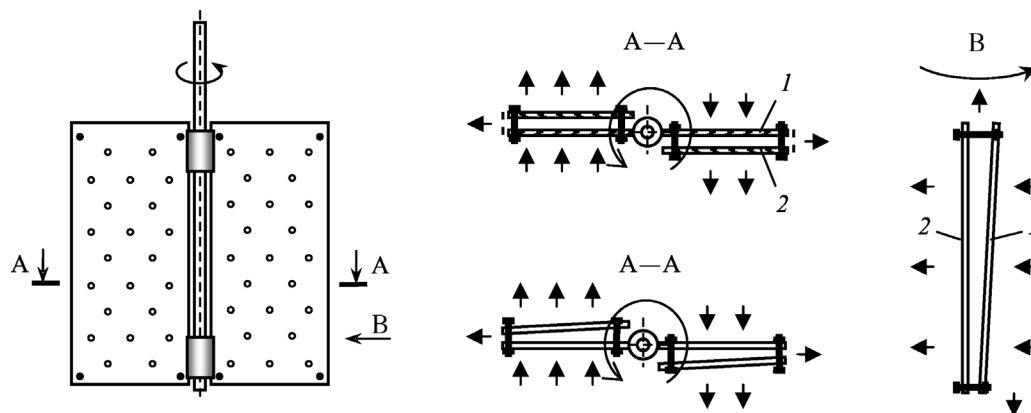


Fig. 3. Pat. No. UA65292U mixing vessel: 1 and 2 are the parts of the blade.

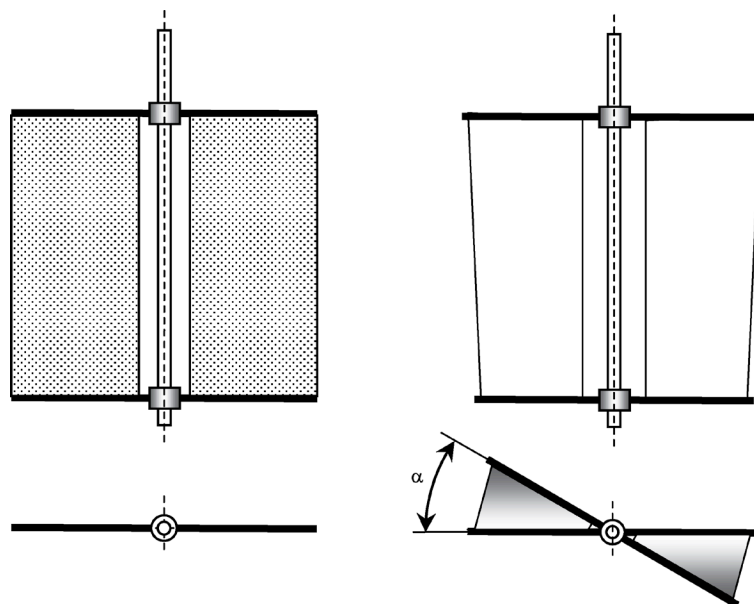


Fig. 4. Pat. UA78566U mixing vessel.

is placed on the shaft with the possibility of free movement along the shaft and joint rotation with the shaft. When the device is operating, the agitator, having positive buoyancy, is located at the free surface level of the liquid, regardless of its volume in the vessel. The torque from the shaft is transmitted through the sleeve to the positive buoyancy agitator, effectively agitating the fluid layers near the free surface. By this means, efficient processing of the entire medium volume is ensured in the vessel.

On the vertical shaft of the Pat. No. UA78566U sheet mixer, two collets are mounted with horizontal brackets. In this case, one of the collets is mounted in such a way as to ensure the possibility of rotation around the shaft and fixation in the required position. Affixed to the brackets are lamellar blades made of an elastic material, for example, silicone-based rubber characterized by high strength, as well as chemical, mechanical, and thermal resistance (Fig. 4). Depending on the required pumping effect in the vessel, the collets rotate relative to each other by an angle α . As a result of the relative sleeve rotation, both sheet blades (due to their elasticity) are converted from vertical to helical, so that when the shaft rotates, the movement of the fluid is established not only in the radial, but also in the axial direction.

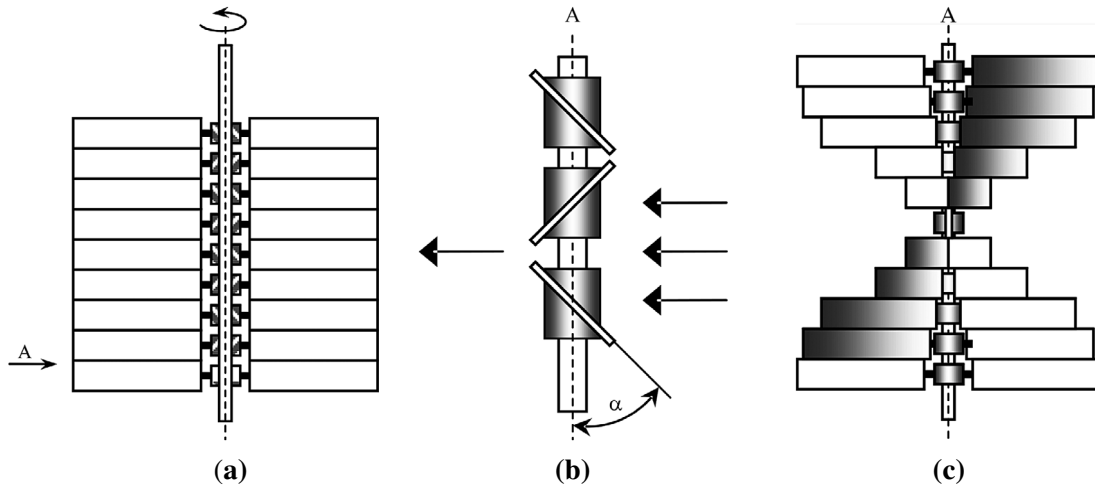


Fig. 5. Pat. No. UA78540U mixing vessel: (a) sheet type; (b) multi-blade type; (c) screw type.

The mixer consists of a corrugated transverse tape fixed on a vertical shaft. The length and, accordingly, the corrugation height of the tape can be changed depending on the shaft rotation frequency, the distance to the walls and bottom of the vessel, and the properties of the mixed fluid (patent application No. US2018110372A1).

Mixers of fixed and adjustable shape are distinguished **by the adjustability of mixer shape**.

The Pat. No. UA75524U vessel for mixing liquids features a vertical shaft equipped with a mixer in the form of tubes connected to the shaft by rods and installed with the possibility of adjusting their inclination relative to the vertical shaft. When the vertical shaft rotates, the liquid located in the sloped tubes is ejected from the ends of the tubes remote from the shaft under the action of centrifugal force. At the same time, due to the continuity of the fluid flow, a new portion of the liquid is sucked into the tubes through the ends close to the shaft. Thus, fluid is circulated in the vessel with the intensity increasing under the ascending slope angle of the tubes relative to the vertical shaft.

On the vertical shaft of the Pat. No. UA78540U mixer, horizontal flat blades are placed pairwise, with each pair mounted on a separate sleeve with the possibility of contact with adjacent blades. Each blade is mounted rotatable relative to its longitudinal axis, and each sleeve is mounted rotatable around the shaft with fixation in the required position (Fig. 5).

Depending on the properties of the mixed fluid, the necessary type of mixer, sheet, multi-blade or screw, is provided due to the relative positioning of the blades and the sleeves.

By turning the adjacent blades along the shaft by an α angle relative to the vertical, the necessary pumping effect of the mixer is provided complemented by the formation of gaps between the blades for effectively dispersing the components of the mixed liquid. On the vertical shaft of the Pat. No. UA93188U adjustable size and shape mixer, transverse blades are articulated at two levels with the ends articulated by longitudinal blades. The transverse blades are mounted to be fixed in the required position. The length of the longitudinal and transverse blades is adjustable (telescopic, Fig. 6). Depending on the properties of the mixed fluid and the necessary hydrodynamic regime in the vessel, by changing the angle of rotation of the transverse blades, as well as by changing the length of the longitudinal and/or transverse blades of the mixer, the necessary dimensions and shape are set, after which the drive of the mixer shaft is turned on and the fluid is mixed in the vessel.

The rods of the Pat. No. UA105210U adjustable size and shape mixer are hinged by the ends to the vertical shaft. The lower and/or upper ends of the rods are mounted on the sleeve assembled on the shaft with the possibility of movement along the shaft and fixation in the required position. The lower and upper ends of the rods are evenly spaced with the formation of the close-ended W letters oriented to each other by bottom side.

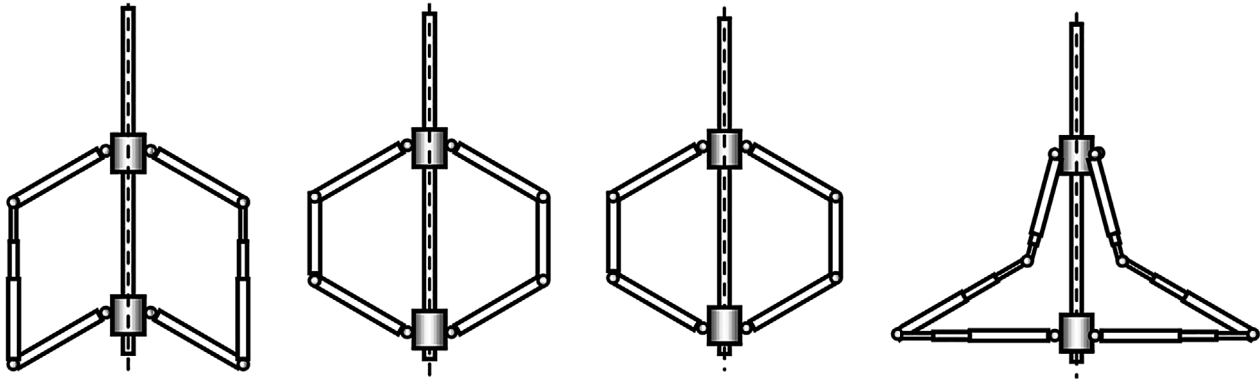


Fig. 6. Pat. No. UA93188U mixer options.

Depending on the vessel diameter and the properties of the fluid processed, the sleeves are mounted and fixed on the shaft at the necessary distance from each other. In this case, the rods are bent to the appropriate value, forming a mixer as an ellipsoid of the appropriate size.

By the even locating the lower and upper ends of the rods with the formation of the close-ended W, the mixer overlaps the entire space between the rods and the shaft with the increase in the efficiency of liquid mixing.

On the shaft of the Pat. No. UA132161U adjustable size and shape mixer, blades are fixed with at least one having an additional articulated blade with the possibility of rotation in its plane and fixation in the required position.

In the design of the Pat. No. UA132177U mixer, horizontal and vertical flat blades are positioned in pairs and a sheet element is mounted between adjacent blades with the possibility of rotation about the horizontal and/or vertical axis and fixation in the required position.

The design of the Pat. No. UA47081U blade mixer also provides for a change in geometry even during operation of the mixer. The working elements of the mixer are made in the form of X-shaped blades with one of the ends pivotally mounted on the shaft and the other articulated on the slider. This “accordion” mixer can be equipped with additional pairs of X-shaped blades with a holed vertical blade and a slot in the joints at the ends of each blade.

In the lower part of the vertical shaft of the device (patent application No. DE102016U4735A1), a collet is mounted with sockets locating curved rods assembled by agitator elements at the ends. Each of the curved rods can be rotated around the longitudinal axis of the corresponding socket and fixed in the required position, thus providing for a change in the spatial position of the mixing elements to ensure effective processing of the liquid depending on its properties.

Mixers with static and dynamic elements (relative to other elements of the mixer) are distinguished by the **mobility of the working elements during mixer operation**.

Mixers with static during its operation elements are characterized by a wide range of technological capabilities and high reliability.

The transverse blades of the frame mixer (inventor’s certificate No. SU386652A1) are pivotally mounted on a vertical shaft with the possibility of rotation in the vertical plane and retraction. The structure is easily mounted and removed from the vessel (in the folded state through the upper hatch of the vessel). When the mixer is mounted in the vessel, its transverse blades are oriented downward under the action of gravity, while the working form of the agitator consists of two rhombuses or parallelograms having a total width greater than the diameter of the upper mounting hatch of the apparatus.

Mixers having elements that move during operation are often used to reduce the starting loads and energy intensity of the device. At standstill, such mixers are typically characterized by a small resistance moment, which gradually increases with increased speed of the mixer shaft.

Such mixers include structures with working elements rotating (usually rotary-lifting) under the action of centrifugal force in the vertical plane, as well as extendable in the radial direction.

The application of a Pat. No. US3455540A mixer with rotary-lifting blades reduces the starting load on the drive motor. When the shaft rotates, the blades gradually occupy a horizontal position, providing effective mixing of the liquid.

The Pat. No. UA102233U mixer, operating on a similar principle, is made of two horizontal blades parallel mounted on a vertical shaft with rotary blades in between suspended on axes spaced apart in radius and height. When the shaft rotates, the blades gradually take a horizontal position, effectively impinging on the processed fluid.

The difference between the design of the Pat. No. UA34301U mixer from the previous one consists in the rotary elements (rods) of the mixer mounted on the disk (uniformly around the circumference of the disk). In this case, the rods are connected to the shaft via tension springs to control the degree of deviation of the rods from the vertical, not only due to the shaft rotation frequency, but also due to the stiffness of the springs.

A more complex design (inventor's certificate No. SU1535611A1) contains rotary work elements mounted in a vertical plane.

The lower pair of mixer blades with a reduced starting load on the drive (inventor's certificate No. SU381375A1) is pivotally mounted on the shaft and connected by rods to an upstream pair of horizontal blades mounted on a floating collet having positive buoyancy.

At the beginning of operation, the floating collect is in its highest position, while the lower hinged blades are maximally adjacent to the shaft. After turning on the drive (with gradually increasing shaft rotation), the lower hinged blades take a horizontal position under the action of centrifugal force.

A similar mixer design (inventor's certificate No. SU1720697A1) disposing an "opening" pair of blades pivotally mounted on the shaft and rods connected to a splined sleeve mounted on the shaft (equipped with a mechanism for its forced movement along the shaft) provides an adjustable "opening" of the blades independently of the shaft rotation frequency.

The Pat. No. UA127909U anchor mixer is implemented with a pair of additional blades pivotally mounted on a hollow vertical shaft through which a rod connecting the blades passes.

If necessary (for example, when changing the viscosity of the processed fluid), the rod ensures rotation of the blades by the required angle.

In the Pat. No. RU2188701C1 frame mixer, the lower transverse blades are pivotally mounted on a vertical shaft. The upper two-shouldered different-sized transverse blades are pivotally mounted in short parts on a movable (along the shaft) spring-loaded cup. The mixer structure is easily mounted and removed from the vessel (through the upper hatch of the vessel). When the shaft rotates, the blades of the mixer are converted from vertically elongated parallelograms into horizontal rectangles under the action of centrifugal force.

The Pat. No. RU2523311C1 mixer is made in the form of an accordion-folded tape with through holes and an upper section mounted on a collet sliding along the vertical shaft. When the shaft rotates, the processed medium actively circulates in the vessel, passing through the holes of the tape. At the end of the mixing process (with an increase in the frequency of shaft rotation or a decrease in the viscosity of the processed medium, for example, when preparing a composition based on epoxy resin), the vertices of the tape folds are pressed against the inner surface of the vessel body, ensuring the destruction of the processed medium wall layer and the uniformity of the finished product.

Mixers with rigid, flexible, elastic, and combined elements are distinguished by the **rigidity of the working elements**.

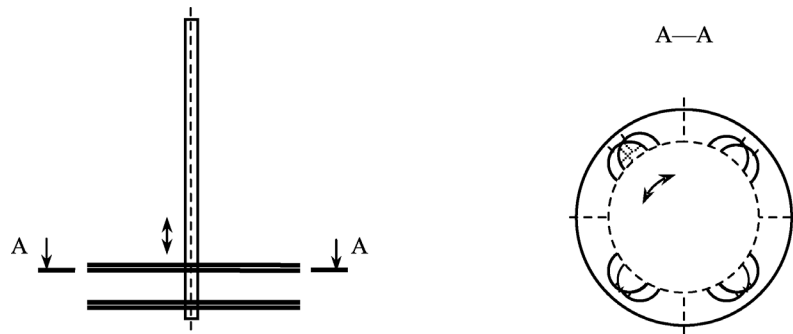


Fig. 7. Pat. No. UA127909U self-adjusting cylindrical mixer.

Flexible working elements of the Pat. No. UA31227U mixer comprise cylindrical tension springs fixed by ends on two parallel disks. The disks are mounted on the shaft with the possibility of mutual rotation and fixing in the required position, ensuring the location of the springs on the surface of a single-band rotation hyperboloid.

Flexible working elements of the Pat. No. UA60258U mixer are made in the form of wires, cables or chains fixed by the ends on two parallel disks with the possibility of adjusting the distance between them.

During the operation of the mixer, the flexible elements acquire a parabolic shape with a vertex remote from the rotating shaft under the action of centrifugal force.

With a decrease in the distance between the disks, the bending of the flexible elements increases.

The following designs of screw (propeller) mixers have been developed: with an adjustable attack angle of the blades (patent application No. WO2016/012348A1); with adjustable degree of disclosure and attack angle of the blades (patent application No. WO2016071567A1 and No. WO2016071568A1).

Mixers with fixed and adjustable effective cross-sections are distinguished by the possibility of **adjusting the effective cross-section of working elements**.

In an adjustable effective cross-section of the vertical sheets of the Pat. No. RU2534796C1 mixer, holes are blocked by a shutter articulated on a corresponding sheet.

When the shaft rotates under the influence of the mixed fluid, the shutters deviate from the vertical position and the fluid passes through the slots opened in this case.

The Pat. No. UA9161U self-adjusting mixer is made in the form of two tightly adjacent perforated cylindrical shells with an open bottom, mounted with the possibility of mutual rotation and fixation in a position providing the necessary degree of mutual overlapping of their perforations.

Such a constructive solution provides an adjustable degree of fluid circulation in the vessel, not only by changing the shaft rotation frequency, but also by changing the effective cross-section of the mixer wall.

Two disks with holes are fixed on the shaft of the Pat. No. UA126630U mixer for liquids with one mounted possible of regulating its position along the shaft. Moreover, each of the disks (over its thickness) is made of two parts installed with the possibility of rotation relative to each other in its plane (Fig. 7).

Depending on the properties of the mixed fluid, the disks are mounted at a certain distance from each other; the individual parts of the corresponding disk are rotated relative to each other in order to ensure the necessary effective cross-section. As a result, when the shaft rotates above and under the mixer, circulation flows of the required intensity are provided.

Mixers with and without additional functions are distinguished by the **presence of additional functions**.

Additional mixer functions include, for example, aeration of the mixed liquid, changing the temperature of the liquid, introducing various additives, etc.

Rotary mixers are traditionally made from metals and their alloys (with and without coatings, such as enamel).

Polymer materials, including composite ones, are also used with the technological properties providing for manufacturing products of various sizes with practically no waste technologies.

Moreover, many polymer composite materials are also characterized by high operational properties: strength, rigidity, wear resistance, chemical and thermal resistance, as well as low density [4].

This article discussed the design of rotary mixers of adjustable shape and/or size, used mainly in equipment for chemical plants. At the same time, despite numerous developments in this area, traditional designs of rotary mixers of fixed shapes and sizes are most in-demand for their high technological and operational qualities. Nevertheless, with modern computer modeling, rotary mixers have been improved, including the development of fundamentally new designs.

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