Modified small size rotor-disc mixer

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Abstract: There is given view of construction of one-step rotor-disc mixer and described work principle in this Thesis. Also given a view of additional elements construction, arranged on working bodies (discs). It is proved experimentally, that making of slots on additional work bodies (teeth) in comparison with solid additional working elements results to significant increase quality of the mixture and performance of the device. It is determined, that to create of the emulsion with certain of dispersed particles the apparatus with modified additional working elements consumes less specific power, this is due to the fact that the working medium passes through the slots, thereby creating additional highly turbulent flows, the directions of which intersect, creating zones of sharp increase and decrease in pressure, which has a positive effect on the emulsification process. In addition specific power consumption of the device with modified additional elements is less than the specific power of the device with solid additional elements, what indicates more highly energy efficiency of supposed construction of rotor-disc mixer. Also given results of experimental research, which certifies theoretical view fully.

Rotor-disc mixers (RDM) are used to create of suspensions and emulsions of high quality. A high efficiency and intensity of emulsification and mixing is a main demand at choice of the apparatus on stage of designing of the production. It has a lot of advantages and well recommended itself as a mixer device in most of technology processes. In this case a quality of the mixture, characterized by sizes of dispersed phase particles, depend on many factors, for example construction of mixer, (performance of working bodies), physical and chemical properties of supplied components, processing time of media and rotor speed. Sizes of dispersed particles and its distribution in given range could be regulated by changing of the rotor rotation speed and processing time of media in the device [1,2]. It is necessary to use other high efficiency constructions of working bodies to reach of need quality of the mixture and increase of performance [3].

To increase of productivity and improve of quality of the mixture, are installed several mixing devices, which is not always economically justified, or is replaced by a mixer with a more advanced design.

Use of several mixers is connected with increase of cash expenses and operating costs. In addition, the system of supply and diversion of components and the mixture will be complicated and reliability of the unit in common will decrease, and energy consumption will increase. To avoid such moments one needs to use rotor-disc mixers with more developed (modified) construction. One of such devices is rotor-disc mixer with modified additional working bodies arranged on main working bodies (discs) (figure 1).
There is forming an area of high pressure on the front side of the tooth on direction of the rotation, and in the back side is forming an area of low pressure during operation of the device due to large rotation speeds, and due it the work medium must bend around the tooth colliding with counter flows. At availability of slots, part of the medium pass through the slot from the area with high pressure to area with low pressure, forming at the same time highly turbulent jets, the directions of which often intersect with each other and with other flows, which leads to the fragmentation of particles of the dispersed phase and their more uniform distribution in the main phase.

Use of rotor-disc mixers with modified additional elements has some advantages compared with mixers with solid additional elements: high efficiency of mixing, productivity, more low specific energy consumption, ad it be explained by increasing the ratio of the sum of the areas of additional elements to the surface area of the disk. In accordance with the practice, use of modified constructions of rotor-disc mixers allow to minimize specific energy consumptions need to mixing and improve quality of the mixture thanks to increase of the processing time. In addition, use of such method allows to efficiency without resorting to replacing the device or its parts [4,5].

Making of transverse slots on additional elements allow to decrease the difference of pressures from different sides of the teeth, and it could be as a prevention of the phenomenon of cavitation that destroys discs.

Use of modifiers of additional working bodies, arranged on discs could be carried out at any stage of the device using as both as during design process and at reconstruction process. Unlike on revision of working disks of the rotor-disc mixer, modification of additional elements don't so much effect to
construction rigidity. And also, in case of processing technology violation during modification of additional element, the main working element (disc) does not become unusable [6,7].

Water ($\rho = 998 \text{ kg/m}^3$, dynamic viscosity $1004 \mu\text{Pa s}$, kinematic viscosity $1.006 \times 10^{-6} \text{ m}^2/\text{s}$, surface tension $0.07 \text{ N/m}$ (at 293K)) and diesel fuel ($\rho = 860 \text{ kg/m}^3$, dynamic viscosity $560 \mu\text{Pa s}$, kinematic viscosity $0.62 \times 10^{-6} \text{ m}^2/\text{s}$ (at 293K)) were used as component of the mixture during the process. The volume of the experimental model of the rotor-disc mixer is $0.8 \text{ dm}^3$, gap between discs is 2 mm, and diameter of discs is 140 mm. During carrying out of experiments, in the body of the device were installed working bodies alternatively, and these working elements were with solid and modified additional elements (width of slots is 2 mm); volumetric flow rate of the medium $Q = 0.2 \text{ m}^3/\text{h}$, the ratio of water/diesel fuel is 1/1.

There are given comparative relations of averaged size of dispersed particles on speed of rotor rotation for disk with solid additional elements and elements, which have transverse slots on figure 2. As it seen of given relations, modified teeth create an emulsion with lower average particle sizes of the dispersed phase over the entire rotation interval, this is due to the creation of additional highly turbulent flows of the medium and an increase in the energy of dissipation. Also it is seen that increase of rotor rotations result to gradual decrease of dispersed phase particles, at this phenomenon could be explained by increase of speed of the medium and, as a consequence, an increase in turbulization, as well as an increase in the energy of dissipation. All these moments indicate that the supposed construction of the rotor-disc mixer is more high energy efficiency.

![Figure 2. Relations of averaged size of dispersed particles on speed of rotor rotation for disk with solid additional elements and elements, which have transverse slots.](image)

Thus, carried out researches showing more high efficiency of rotor-disc mixers with additional working elements, which have a modification in the form of transverse slots in comparison with devices with solid additional elements. It is determined that creation of additional transverse slits on additional elements (teeth) results to decrease dispersed particles size to $\sim 15\% - 30\%$, but at the same time energy consumption increases by $\sim 10\% - 15\%$, what makes more perspective use of such a method of modifying the mixer design more promising at specific technological processes.

Use of rotor-disc mixers for processing of mediums in liquid-gas and liquids solid particles connected with some features. There are the following features of mixing of gas-liquid heterogeneous system:

- a sharp change in the density of the medium in the first stage of mixing (between the upper and movable disk);
• the coalescence process proceeds quite quickly, especially with a large volume content of the gas phase;
• the occurrence of stagnant zones (air jams) in the volume of the mixer at low productivity.

Rotor-disc mixers are small-sized mixing devices, and it is mean that the total volume of the device and volume of working bodies are commensurate. There isn't need to make any serious design changes to use of rotor-disc mixers at processing of gas-liquid system, and common rules on increase of productivity and mixing efficiency are the same as for the system liquid-liquid. However when re-profiling of the rotor-disc mixer from liquid-liquid system it is need to take in account for liquid-gas system, that the consumed power will decrease (at same parameters of rotation speed, medium consumption an etc.). It could be explained that the density of processing mixture will decrease abruptly. As it known the consumed power for mixing is proportional to the energy spent on crushing the droplets of the dispersed phase and the density of the medium being processed [7].

At mixing of liquid-solid parts there are take place some processes: crushing of solid particles of the material and their distribution in the volume of the apparatus. Unlike on liquid and gas, solid particles practically do not stick together into larger lumps, but due to the high density of the dispersed phase, the particles easily settle. Therefore at making of devices for mixing of liquid-solid particles systems it is necessary to avoid areas with low rates of medium movement and places where solid particles settle due to centrifugal force. In addition at mixing of such systems there is takes place a large abrasive wear, and therefore devices have a low turnaround time. To increase of the resource, need use some methods, at the first working disks and additional parts are made of more solid materials with more thick width of wall. Also there is use a processing of surface which increase wear resistance of the part, e.g. cementation, shot blasting, etc. Using of sleeves, installed in a body of a device, which protect inner surface of the body on a wear. In the most cases sleeves made of polymeric materials, because these materials are cheaper than metal ones, easily distilled, have good wear-resistant properties. Use of seals, which protect bearings on ingress of abrasive particles and liquids.

In accordance with above said, rotor-disc mixers are universal mixing devices and could be use at to mix of various mediums without any significant constructive changes.

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