Stirring in liquid media

Stirring liquids, pastes and solid bulk materials - one of the most common processes of chemical technology. Most often encountered in the art of mixing liquid media processes. Under stirring liquids understand the process of mixing multiple macroscopic elements relative volume of the liquid medium under the action of momentum transfer medium with a mechanical stirrer, gas jet or liquid.
Mixing liquid media used for the following main objectives: 1) intensification of heat and mass transfer processes, including in the presence of a chemical reaction; 2) a uniform distribution of solid particles in a liquid volume (in the preparation of suspensions) and uniform distribution and crushing to the desired dispersion of liquid in a liquid (in the preparation of emulsions) in the liquid or gas (with bubbling).
Stirring of liquid media can be done in different ways: the rotational or oscillatory motion stirrers (mechanical agitation); by bubbling gas through a liquid layer (air mixing); by pumping fluid through the nozzle becomes turbulent; pumping liquid pump in a closed loop (circular mixing).

Stirring in liquid media

Apparatuses with mixing devices widely used in chemical engineering for such processes as evaporation, crystallization, absorption, extraction, and others.
While stirring, the temperature and concentration gradients in the medium filling apparatus tend to the minimum value. Therefore, apparatuses with a stirrer, such as the structure flows closest to the ideal mixing pattern.
The mixing process is characterized by the intensity and efficiency as well as energy consumption for its holding.
Mixing intensity is determined by the amount of energy N, supplied to the unit volume of the mixed liquid V per unit time (N / V) or to a unit mass of the mixed liquid (N / V□). The intensification of the mixing process enhances the performance of the installed equipment, or reduce the amount projected.
By mixing efficiency understand the technological effect of the mixing process, characterizing the quality of the process. Depending on the purpose of mixing this characteristic is expressed in various ways. For example, using heat to intensify mixing, mass transfer and chemical processes, it is possible to express the efficiency ratio of the kinetic coefficients with stirring and without it. In the preparation of suspensions and emulsions can be characterized by the efficiency of mixing uniformity of the phase distribution in a suspension or emulsion.

Mechanical agitation.
Movement of fluid in the apparatus with the stirrer

In industry for mixing mainly using the mechanical stirrer with rotary motion. When using such mixers arises complex three-dimensional fluid flow (tangential, radial, axial) with a predominant circumferential velocity component. Tangential flow, which is formed during operation of all types of stirrers, is primary. Typically, the average value of the circumferential (tangential) velocity component (WT) is significantly higher than the average values of both the radial (WP), and axial, or axial (wa) components.

For the rotational motion of a fluid system of Navier-Stokes equations can be written as follows:

? (1)

$$\frac{\partial p}{\partial r} = \rho \frac{w_\tau^2}{r}, \qquad \mu \frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial (w_\tau r)}{\partial r}\right) = 0; \qquad \frac{\partial p}{\partial z} = -\rho g .$$

where WT - the tangential component of the velocity.

In the case of a flat rotary motion about the axis z (WP = 0, wa = 0), the system (1) has a general solution: WT = C1r + C2 / r (2)

For r = 0, WT = 0 and C2 = 0, respectively, for the region, located in the center of a rotating mass of fluid, the steady movement wr = □r (where □ - the angular velocity). Thus, along the axis of rotation of the liquid in the region 0 <r <RB there is a cylindrical vortex radius RB. From equation (2) it follows that in the region outside of the cylindrical vortex WT = C2 / r, where C2 = □rv. Then the peripheral region of the tangential component of the velocity

WT = □rv / r

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Comparison of theoretical and experimental fluid tangential velocity curve in the device with a rotating agitator (Fig. 1) shows that there is some transition region II between the region I and the central vortex peripheral region III.

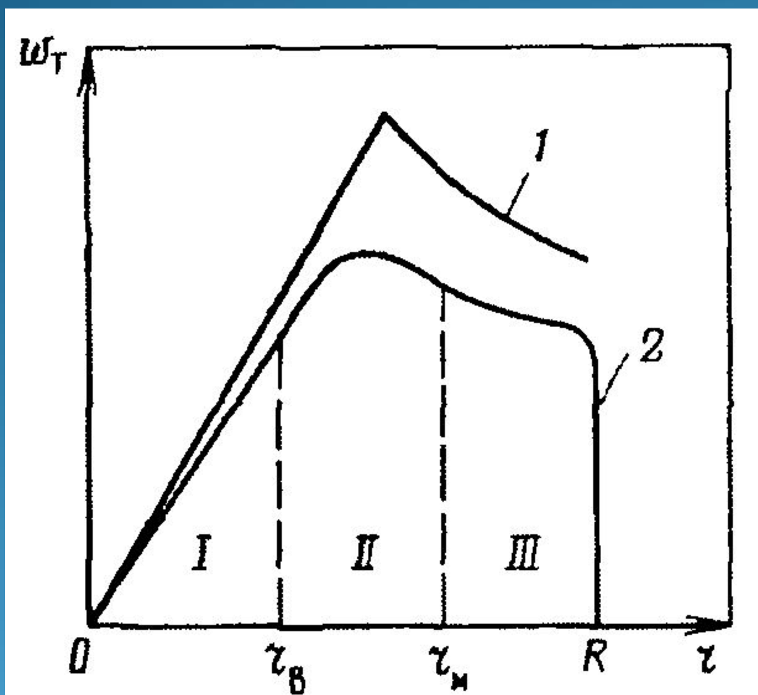

Fig. 1. Theoretical (1) and experimental (2) The tangential liquid velocity curves in the device with a rotating stirrer:
I - the central region of the cylindrical vortex
II - the transition region,
III - peripheral region

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Under the influence of the centrifugal force produced by rotation of any type stirrer with a sufficiently high frequency, the liquid flows from the blades in the radial direction. When he reached the vessel wall, the stream is divided into two: one goes up, the other - down. Occurrence radial flow leads to the fact that the transition region is created in the reduced pressure zone, and which directs the fluid flowing from the free liquid surface and from the bottom of the vessel, i.e. there is axial (axial) flow moving in the upper part of the vessel from the top down to the stirrer.
Thus, the machine creates a stable axial flow, or a steady circulation (Fig. 2).

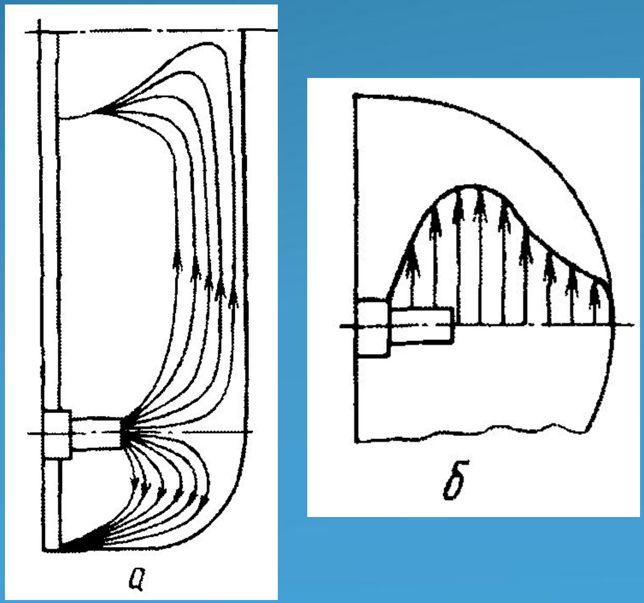

Fig. 2. The trajectories of particle motion in the fluid machine with a stirrer (a) and the velocity curve (b)

Mechanical agitation.
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The volume of the circulating liquid per unit time in the device with an agitator called pumping effect, which is an important feature of the agitator: the greater pumping effect, the better is the mixing process apparatus. In the case of predominantly radial flow created by the stirrer, pump effect Vp is determined by the expression

Vp = □dmbwr,

where WP - average radial velocity of the fluid, and wp □ dmn.

As for geometrically similar impellers ratio b / dm - a constant, we can write

Vp = Cpndm3 (3)

where Cp - constant for a given type mixers.

Mechanical agitation.
Movement of fluid in the apparatus with the stirrer

In the case of predominantly axial (axial) flow created by a stirrer, pump effect void ratio is expressed as follows:

$$Vo = \square dm2\ wo / 4,$$

where wo - the average liquid velocity in the axial direction, the wo ~ nS (Where S - the step mixer).

As for geometrically similar mixers S / dm = const, we obtain the expression

$$Vo = Sondm3, (3a)$$

identical to equation (3). Thus, a pumping effect is strongly dependent on the design of the mixer and the frequency of rotation. A significant influence on him has stirred the liquid viscosity: viscosity with increasing pump effect decreases, which reduces the efficiency of the mixing process.

The modified Reynolds number Re stirrer in case of mechanical mixing of the liquid medium is expressed as follows (noting that □dmn □ =): = REM ndm2□ / □ (4)

where dm - impeller diameter, m; n - speed stirrer-1.

In laminar flows (REM <10) in the apparatus with a stirrer there underdeveloped for a three-dimensional free-circulation. The central cylindrical vortices are omitted since their diameters are less than the diameter of the agitator shaft. The phone really exists peripheral and transitional flow region.

As the flow of turbulence (10 <REM <103) is formed by a forced circulation, and the machine does not only exist peripheral and transition region, but the region is planned central cylindrical vortices.

When developed turbulent flow (REM> 104) forced circulation provides an intensive three-dimensional throughout the mass of liquid in the device. The area of the central cylindrical vortex develops, reaching (in order of magnitude) the size of the transition and peripheral areas.

In operation, rotating mechanical stirrer occurs on the surface of the liquid crater depth which increases with increasing impeller speed (in the limit it can reach the bottom of the vessel). This phenomenon has a negative impact on mixing efficiency and significantly reduces the stability of the agitator. On the depth and shape of the funnel is greatly affected by the impeller diameter and speed of rotation.

The energy expended in the process of mixing

The value of KN is called the criterion of power, or a modified Euler criterion (for stirrers); it is also called centrifugal Euler criterion.

KN = N / (□n3dm5) (5)

where N - power expended blade mixer to overcome the fluid resistance.

Indeed, Euler criterion Eu = □R / (□w2), and w ~ nd. Hydraulic resistance when rotating mixer in a liquid medium □R ~ N / (ndm3).
Then

Eum = N / (□n3dm5) = KN

Then the generalized hydrodynamic equations for the mixing process takes the form of liquid media

KN = □1 (REM, Fr m, G1, G2, ...). (6)

where Frm = w2 / (gd) = n2dm / g - Froude criterion for the mixing process.
In those cases where the effect of gravity is negligible (or no funnel has a small depth), the equation (6) can be simplified and reduced to the form

KN = □2 (REM, G1, G2, ...), or KN = A□ (Remm G1p □ □ G2q ...) (7)

where the values of k, m, p, q is determined empirically.

The design of agitators

By rotation speed stirrers conventionally divided into two groups: low-speed (anchor, frame and other, in which the circumferential speed of the blade tips of about 1 m / s) and high-speed (propeller, turbine, and others in which the circumferential speed of about 10 m / s).

The apparatus structural element directly destined to bring the liquid into motion is a stirrer. As practice shows, most mixing tasks can be successfully solved by the use of a limited number of agitators designs. In this case there are most typical applications geometrical relationships and ranges of individual types of mixers. For example, for mixing highly viscous fluids in laminar mode using tape, scrapers and screw mixers (Fig. 3a, b, c). The scraper agitator is used primarily for enhancement of heat transfer; scrapers attached via springs, thereby providing a snug fit to the wall of the apparatus.

For the mixing of liquids of relatively high viscosity (generally heat input, ie machines with a jacket) used low-speed mixer - anchor and frame (Figure 3g, h.). The ratio Da / dm these mixers is low (1.05-1.25), and therefore they are often used under stirring suspensions, particles which are characterized by a tendency to stick to the wall.

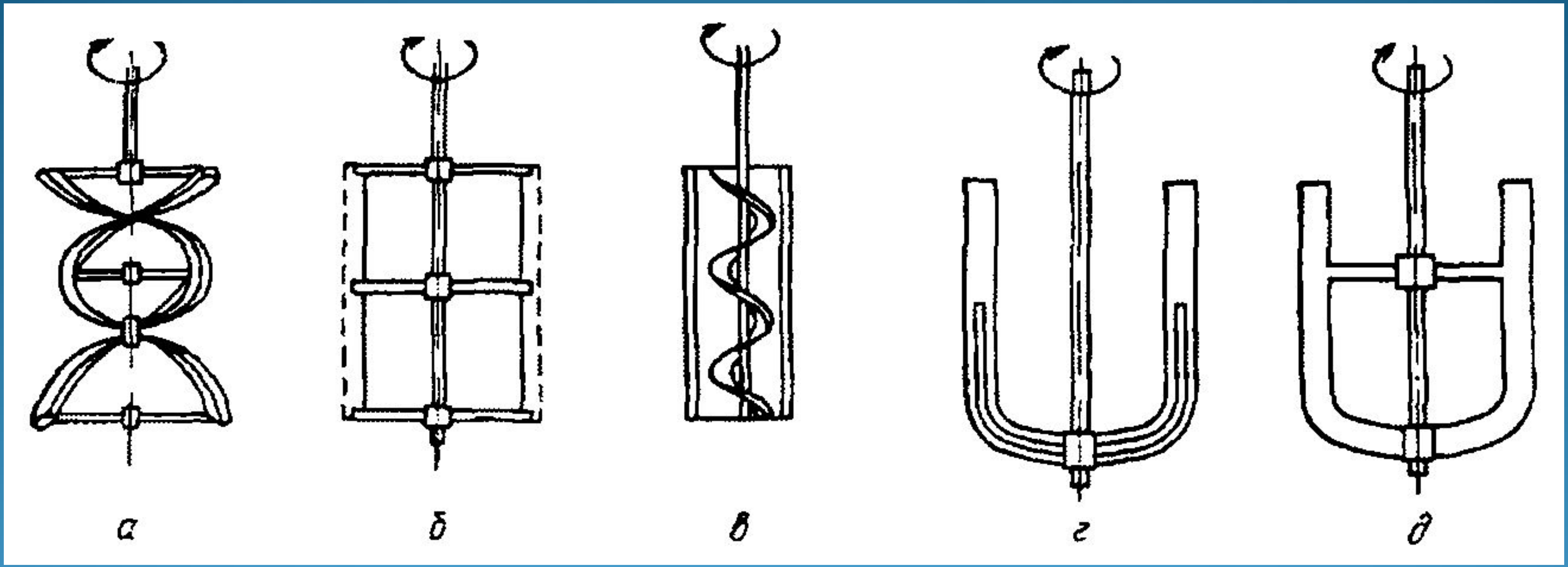

Fig. 3. Mixers for mixing highly viscous media (a-c) and medium viscosity fluids (d, e): a - band; b - scraper; in - auger with a rough guide; g - anchor; d - frame

Typically, the apparatus for mixing is a vertical vessel with a stirrer, wherein the rotation axis coincides with the axis of the machine (Fig. 4). Depending on the circumstances of a particular process, the volume of the device with a mixer may range from a few tenths to a few thousand cubic meters. The main components of such devices are the body, the drive shaft and agitator. Housing unit usually consists of a vertical cylindrical shell 5, the cover 2, on which the drive agitator 1 and 9. At the bottom of the covers are placed and pipes 4 and 11 for the supply and removal of substances, compressed gas supply, installation of instrumentation and so on. n. For the supply and removal apparatus body heat supply jacket 7. The drive of the mixing device is usually a motor coupled to the shaft of the agitator directly or reduction gear.

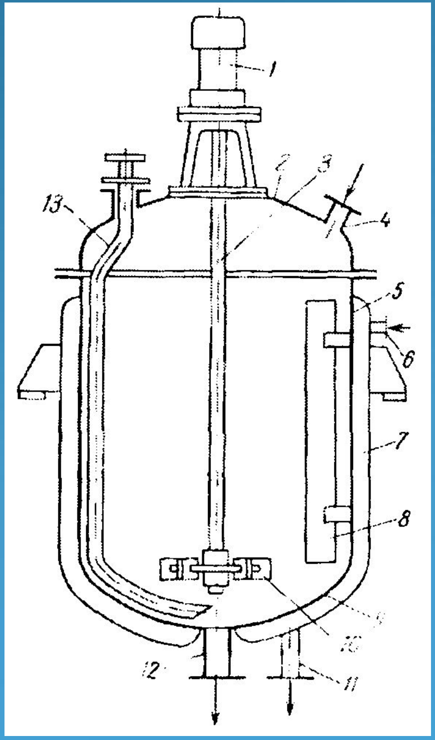

Fig. 4. The device with a mixer:
1 - with a drive motor;
2 - a cover;
3 - the agitator shaft;
4 - fitting for the compressed gas;
5 - the case;
6 and 11 - inlet and outlet fittings coolant;
7 - shirt, 8 - baffle,
9 - the bottom 10 - agitator;
12 - Product discharge fitting,
13 - perelavlivaniya pipe.