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Mechanical filtration, based on elective concentration of particles, as an innovative method of water treatment

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Abstract. The paper describes a method for purification of waste water in a hydrocyclone by solid phase particles. To achieve more efficient cleaning, a technique is proposed for calculating the separation processes in hydrocyclones based on the equation for the radial motion of a particle associated with an air bubble.

Most natural and process fluids represent multiphase heterogeneous systems containing various inclusions and are characterized by nonlinear behavior in porous media. The effects observed in the filtration of heterogeneous systems are very diverse, which predetermines a qualitatively different form of the filtration laws for them [1].

The process of extracting suspended particles from wastewater into the field of centrifugal forces in the hydrocyclone allows to intensify the process and achieve an almost complete recovery of the particles of the solid phase by separating the particles of the smallest fractions [2].

The hydrocyclone (Fig. 1) consists of a cylindrical chamber, into which tangentially through the inlet branch *1*, installed in its upper part, at increased pressure (up to 0.8 MPa), production wastewater is fed, preliminarily saturated with dissolved gas (nitrogen), and of a conical part with a cone angle α. The suspension, that enters the hydrocyclone, drains to form a rotating film, down its walls, having a circumferential V_f, axial V_z and radial V_r velocity components [3]. When the pressure decreases to the atmospheric one, a supersaturation of the dissolved gas is created and the suspension «boils». The solid phase particles under the action of the centrifugal force move to the wall of the hydrocyclone body, and the gas bubbles under the action of Archimedes' pushing centripetal force move towards them to the surface of the film. In the collision of the solid phase particles with gas bubbles formation of flotocomplexes takes place, which carry out the solid phase particles onto the surface of the film into the foam layer, which is removed through the upper branch pipe *2*. Besides, the solid phase particles serve as direct centers for the formation of gas bubbles that are released when the pressure decreases, which leads to a significant increase in the kinetic coefficient of pressure flotation. The clarified suspension is removed from the device through the lower discharge pipe *3* [3].

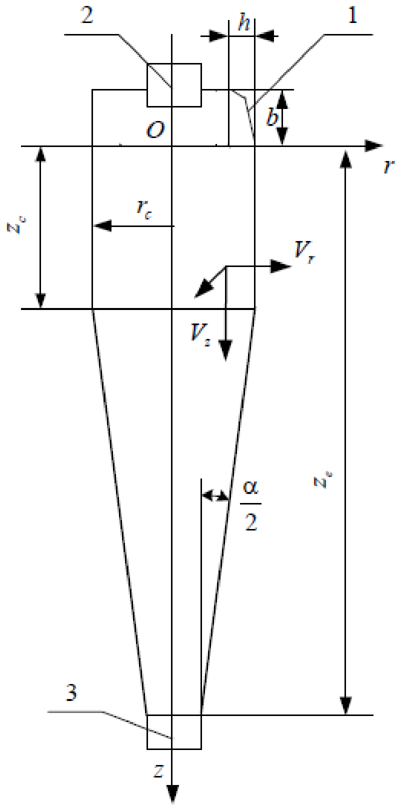

Fig. 1 - Scheme of wastewater treatment in a hydrocyclone under pressure

The simplicity of construction and the absence of moving parts are advantages that distinguish hydrocyclones from other centrifugal principle devices. The separation of heterogeneous systems in the devices of the hydrocyclone principle of operation can be intensified by using the flotation process [4].

We have proposed a technique for calculating separation processes in hydrocyclones based on the equation for the radial motion of a particle associated with an air bubble [5],

$$m\frac{d^2r}{dt^2} = \pm m\frac{V_t^2}{r}\left(1-\frac{\rho_c}{\rho_f}\right) \mp \beta\left(V_r \pm \frac{dr}{dt}\right) \mp F, \quad (1)$$

where the upper sign under the terms refers to the case of the motion of the particle-bubble system to the wall of the device, and the lower one to the axis of the device; m is a particle mass; V_i is a tangential velocity component; V_r is a radial velocity component; ρ_c; ρ_f is a density of dispersion medium and dispersed phase, respectively; r is a current radius on which the bubble particle is located; β is a Stokes' resistance coefficient; F is Archimedes' force acting on an air bubble.

Taking into account the specific hydrodynamics of the hydrocyclones, after performing a series of transformations, we find the expression for the time function of the displacement

$$t=-0.5\left(\frac{m}{\beta}\right) ln\left|\frac{\frac{A'}{B^*}-r^2}{\frac{A'}{B^*}-r_1^2}\right| - 1.5\left(\frac{m}{\beta}\right) ln\left|\frac{r^2}{r_1^2}\frac{\frac{A'}{B^*}-r^2}{\frac{A'}{B^*}-r_1^2}\right| \mp ln\left|\frac{\frac{A'}{B^*}-r^2}{\frac{A'}{B^*}-r_1^2}\right| \quad (2)$$

$$B^* = \frac{Q_в}{2\pi h}, \quad (3)$$

$$A' = \frac{\pi(A^*)^2}{6\beta}\left[d_T^3\rho_\Phi\left(1-\frac{\rho_-}{\rho_f}\right) - d_n^3\rho_c\right], \quad (4)$$

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where d_T is diameter of a solid particle; diameter of an air bubble d_n can be determined in various ways, for example, through the critical value of the Weber number.

The condition for coupling a bubble to a particle

$$\pi\frac{d_n}{2}\sigma_{zh}sin\theta \geq \frac{\pi d_n^3}{6}\rho_c\frac{A^2}{r^3}+\frac{\pi d_T^3}{6}\rho_f\frac{A^2}{r^3}+\frac{\pi a^2}{4}(\frac{4\sigma_{zhg}}{d_n}-1.3\rho_c d_n\frac{A^2}{r^3})+F_{mp} \quad (5)$$

where a diameter of the circle along which the bubble is attached to the surface of the particle; θ is a contact angle of wetting; σ_{zhg} is a surface tension on the liquid-gas section; F_{mp} is a force of viscous friction; A is a constant value for given geometric and mode parameters of the hydrocyclone operation.

Furthermore, a dependence was obtained to determine the basic size of the hydrocyclone - D:

$$D=\frac{2.56V_{vh}(tga)^{0.4}(d_T^3-nd_n^3)}{ndVtg(\frac{a}{2})} \quad (6)$$

where d = d_n when $d_n > d_T$ or d = d_T when $d_n < d_T$, in its turn, in this equation $d_r = d_{min}$ is a minimum diameter of solid particles (droplets), which should be separated in a cylindrical conical cyclone with a diameter of the cylindrical part *D; V_{vh}* is a speed of flow velocity in a feed nozzle of the hydrocyclone with a diameter d_{vh}*; a* is an angle of the conical body part; $n=\frac{\rho_c}{\rho_f-\rho_c}$; v is a kinematic viscosity of the suspension (emulsion) flow.

Thus, the process of separation of heterogeneous liquid systems in the field of centrifugal forces in hydrocyclones provides high efficiency. This method is relevant for the treatment of waste water in the oil refining sector, since it is a resource-saving.

References

[1] Lagutkin M G and Pavlovsky G V 1999 Analysis of possibility of organizing the flotation process in a hydrocyclone *Thesis report of 12 International scien. conf. «Mathematical methods in engineering and technology»* vol 2 (Velikiy Novgorod) pp 214-215

[2] Masagutov D F, Pushnov A S and Kashapov N F 2014 Influence of geometric characteristics of regular structured attachments on hydraulic resistance and efficiency of heat and mass transfer processes *Chemical Technology* **9** vol 15 pp 564-571

[3] Yablonsky V O 2012 Choice of design and modes of operation of the hydrocyclone for wastewater treatment of PVC production by pressure flotation *Bulletin of Volgograd State Technical University* **5** vol 1 pp 68-70

[4] Mongait I L and Rodziller I D 1958 *Methods of wastewater treatment* (Moscow: State scientific and technical edit) p 251

[5] Karataev O R, Markina A A and Shamsutdinova Z R 2014 Wastewater treatment of petrochemical industry using crystallization and flotation methods *Bulletin of Kazan Technological University* vol 17 pp 351-355