METHOD FOR CALCULATION OF SEPARATION INDEXES OF SUSPENSIONS IN A CYLINDRICAL COCURRENT HYDROCYLONE

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UDC 621.928.37

Recently, new designs of hydrocyclones have appeared for which the familiar [1-3] design-calculation methods are unacceptable, e.g., for those such as cylindrical cocurrent hydrocyclones with discharge of mixture-separation products at several radii (Fig. 1). Such units can find wide use; therefore, a method has been proposed for calculation of suspension-separation (classification) indexes for these hydrocyclones.

The equation for determination of the recovery $S_i$ of solid-phase particles of the considered fineness class was obtained in the form of the expression [2]

$$S_i = \frac{A}{R} \left[ r_{i+1} \sqrt{r_{i+1}^2 - B} - r_i \sqrt{r_i^2 - B} \right] - \ln \left( \frac{r_i + \sqrt{r_i^2 - B}}{r_{i+1} + \sqrt{r_{i+1}^2 - B}} \right),$$

where $A = \frac{2}{(R^2 - r_0^2)}$ and $B = \frac{t d^2 V_{\phi}^2 (\rho_p - \rho_\ell)}{9 \rho_\ell V_s}$ (here $R$ and $r_0$ are the radii of the hydrocyclone housing and the central displacer, respectively; $t$ is the residence time of the particles in the hydrocyclone, determined according to the conditions of [2]; $d$ is the diameter of the considered particle; $V_{\phi}$ is the tangential component of the flow rate in the

![Fig. 1. Design of cocurrent hydrocyclone with discharge of mixture-separation products through ducts located at different radii: $Q_1$, $Q_2$, and $Q_3$ are the outputs of the hydrocyclone at the first, second, and third ducts, respectively.](image-url)
cylindrical hydrocyclone; \( \rho_p \) and \( \rho_L \) are the densities of the particles and the liquid, respectively; \( \nu_s \) is the kinematic viscosity of the suspension; and \( r_i \) and \( r_{i+1} \) are the radii between which product is withdrawn from the axial discharge zone.

For the considered hydrocyclone design (see Fig. 1), in the case of product discharge by three streams, the recovery of the solid phase in accordance with [2] for each fraction through the first zone can be obtained from the equation

\[
S_i = \frac{A}{2} \left[ R_i \sqrt{R_i^2 - B} - r_i \sqrt{r_i^2 - B} - B \ln \left( R_i + \sqrt{R_i^2 - B} \right) - \ln \left( r_i + \sqrt{r_i^2 - B} \right) \right],
\]

where \( r = \frac{vt^2}{9 \eta \nu_s} (\rho_p - \rho_L) + r_s^2 \) is the current radius limiting the space within which there will be no particles of the given fineness class after time \( t \), and \( R_i \) is the outside radius of the first discharge zone. Equation (1) is valid for \( r < R_i \). In this case, we determine the recovery through the second zone according to the following equation:

\[
S_2 = \frac{A}{2} \left[ R_2 \sqrt{R_2^2 - B} - R_1 \sqrt{R_1^2 - B} - B \ln \left( R_2 + \sqrt{R_2^2 - B} \right) - \ln \left( R_1 + \sqrt{R_1^2 - B} \right) \right],
\]

where \( R_2 \) is the outside radius of the second discharge zone.

If \( r \geq R_i \) and the recovery of particles of the considered fineness class through the first discharge zone is equal to zero, the recovery of the particles through the second zone will be determined from the expression

\[
S_2 = \frac{A}{2} \left[ R_2^2 - r_i \sqrt{r_i^2 - B} - B \ln \left( R_2 + \sqrt{R_2^2 - B} \right) - \ln \left( r_i + \sqrt{r_i^2 - B} \right) \right].
\]

The recovery through the duct of the third (wall) zone can be determined from the material-balance equation written in the form of the expression \( S_3 = 1 - S_1 - S_2 \). However, it should be noted that this picture of the solid-material distribution in the considered hydrocyclone can be transformed by nonequilibrium withdrawal of the leaving streams from each zone, e.g., because of change of the diameters of the discharge pipes. Thus, the presented dependences describe a field of mass concentrations of the solid material in the hydrocyclone before the discharge holes and do not take into account the product-discharge conditions; therefore, in what follows, let us call the recovery values calculated from these dependences arbitrary \( (S_i)_{arb} \).

According to the preceding discussions, the arbitrary yield of the material \( (G_{if})_{arb} \) of the considered fineness class with uniform discharge of separation products will be \( (G_{if})_{arb} = (S_{if})_{arb} x \), where \( G \) is the mass of the solid material contained in the initial suspension fed to separation, and \( x \) is the mass fraction of particles of the considered fineness class in the initial suspension.

In this case, the arbitrary mass concentration of the streams leaving the hydrocyclone \( (C_i)_{arb} \), ignoring their redistribution among themselves, is defined as the quotient from division of the mass of the particles discharged through the appropriate zone to some arbitrary liquid flow rate:

\[
(C_i)_{arb} = \frac{\sum_{k=1}^{n} (G_{if})_{arb}}{Q_{tot} \left( \frac{r_{i+1} - r_i}{R^2 - r_i^2} \right)},
\]

where \( n \) is the number of intervals into which the entire range of the fractional distribution of the solid phase of the initial suspension is divided, and \( Q_{tot} \) is the total output of the hydrocyclone determined according to [1].

Using the obtained dependences and taking into account that the redistribution of the solid phase at the outlet of the unit occurs only between neighboring zones and that the