IRSTI 61.13.15

B.T. Tazhibayeva[1] – *main author*,
L.M. Musabekova[2], A.M. Brener[3]
V.G. Golubev[4], L.M. Ulyev[5], Z. Kobeyeva[6]

[1]PhD student, [2,3,4,5]Doctor of Technical Sciences, [6]PhD

ORCID *[1]https://orcid.org/0009-0007-2973-0065 [2]https://orcid.org/0000-0001-8712-2446*
[3]https://orcid.org/0000-0001-7041-0177 [4]https://orcid.org/0000-0001-7370-3872
[5]https://orcid.org/0000-0002-2732-6444 [6]https://orcid.org/0000-0002-7471-5098

[1,3,4,6]M. Auezov South Kazakhstan University, Shymkent, Kazakhstan
[2]South Kazakhstan Medical Academy, Shymkent, Kazakhstan
[5]Tomsk Polytechnic University, Tomsk, Russia

@ *[1]mleyla@bk.ru*

https://doi.org/10.55956/NTYA6347

SIMULATION OF SUSPENSIONS SEDIMENTATION INTO VESSELS AND THROUGH-FLOWING DEVICES

Abstract. The two novel models of sedimentation of polydisperse suspensions have been submitted. The first model has been developed for the sedimentation of a polydisperse suspension in a vessel. This model is a development of the general model developed in the authors previous works, based on a continuous distribution function. Use a continuous function of particle size distribution of the dispersed phase allows us to buid the model in the form of a diffusion-type equation with source terms. The second model is devoted to describing the process of sedimentation of a polydisperse suspension in a flow-through systems. A concept has been developed for calculating the distribution of the dispersed phase in the flow leaving the apparatus based on a pricipally new methodology of boundary deposition curves. The developed models make it possible to calculate the evolution of the position of the sedimentation front and the sediment surface both along the height of the vessel and along longitudinal coordinate of the through-flowing apparatuses. An expressions and computer code for calculating the evolution of the sedimentation fronts have been developed, that is of importance for calculating the kinetics of sedimentation of polydisperse suspensions.

Keywords: model of sedimentation, polydisperse suspensions, gravitational sedimentation, boundary deposition curves, sedimentation in through-flowing systems.

Tazhibayeva B.T., Musabekova L.M., Brener A.M., Golubev V.G., Ulyev L.M., Kobeyeva Z. Simulation of suspensions sedimentation into vessels and through-flowing // Mechanics and Technology / Scientific journal. – 2024. – No.3(85). – P.317-327. https://doi.org/10.55956/NTYA6347

Introduction. Sedimentation processes are extremely widespread both in nature [1] and in various technological processes [2]. These are processes and phenomena in various nature bodies of water: from rivers and lakes – to seas and oceans [3]; volcanic events, mudflows [4], groundwater flow [5] and seepage through dams [6]. These are also phenomena that occur in living nature: from micro [7] to macro levels [8]. In industry, these are processes occurring in devices for the production and purification of target technological suspensions [9], as well as during the purification of emissions [10]. Sedimentation processes play an important role in pharmacology [11] and medicine, at the level of drug production [12] and laboratory analysis [13] and even therapeutic techniques [14].

It is necessary to distinguish between the characteristics of sedimentation in stationary reservoirs and in flow-through systems and apparatuses.

Sedimentation processes are widely spread in nature and are also an important part of various technological processes [15]. At the same time, sedimentation, especially when it comes to polydisperse suspensions, is accompanied by various attendant processes, and it can occur in different modes [16], which makes it a very complex problem to construct adequate mathematical models that are convenient for use in engineering calculations [17]. In the case of a bidisperse suspension, the kinetic curve of sedimentation consists of three linear sections [18]. However, such a model cannot be developed for the case when aggregation of different fractions can be possible [19]. If the division into a conditionally coarse and conditionally fine fraction does not provide a correct description of the fractional composition of the suspension, then the model [18] does not work. In the case of highly concentrated dispersions, in addition to the possibility of aggregation of fractions, it is also necessary to take into account the mutual influence of different fractions on the rate of aggregation of each other [20]. Therefore, the problem of theoretical description of sedimentation of highly concentrated dispersions [21] is far from a satisfactory solution [22]. Engineering models should not be too complex, adequately describing the quantitative regularities of the process [23], and provide correct estimates of the control parameters [24], which is very important for the optimal calculation of equipment [25]. In this paper, a macroscopic sedimentation model based on the particle distribution function in a polydisperse suspension [26] is proposed for discussion.

The results obtained can be applied to fluids with suspensions of fairly coarse particles in a turbulent flow regime [21]. During the sedimentation of fine particles in slow flows, the role of flow velocity fluctuations on the intensity of sedimentation increases [22]. During the sedimentation of fine particles in slow flows, the role of flow velocity fluctuations on the intensity of sedimentation increases [23]. The work demonstrates that the presence of a horizontal velocity shear can further influence this vertical transport [24]. The work devotes to experimental investigation of sediment accumulation impacts the operational efficiency of water pumps [25]. The first mentioned model allows calculating the diffusion coefficient during sedimentation of a highly concentrated polydisperse suspension in a vessel taking into account the constraint of movement of various fractions of the dispersed phase [23]. Although attempts to construct such models have been made previously [25], further work is required to develop a generalized mathematical description and identify the main control parameters of the model.

In the presented work, a generalized model for difficult sedimentation not accompanied by aggregation in the dispersed phase is developed. An analysis of the presented model as applied to sedimentation with mutual aggregation of various fractions will be carried out and presented in subsequent publications.

The first submitted in the paper model devotes to describing sedimentation process into vessels. This model basically corresponds to the model developed earlier and described in the previous authors work [26], developing it, however, somewhat. The second model in this work devotes to describing the process of sedimentation in a through-flowing apparatuses. This model is original, and it is submitted for the first time in the paper.

Materials and methods. The diffusion model of sedimentation is based on the idea that, due to the different sedimentation rates of different fractions, several fronts of suspension sedimentation are formed. In this case, there are two main moving free boundaries: the sedimentation front S and the surface of the forming layer of sediment H^*. A further generalization of the model for describing the sedimentation of polydisperse suspensions is based on a diffusion-type equation. A similar equation for each i-th conditional density ρ_i of the fraction has the form [26]:

$$\frac{\partial \rho_i}{\partial t} = D_{eff(i)} \frac{\partial^2 \rho_i}{\partial y^2} + I(\rho_i) \tag{1}$$

Here $D_{eff(i)}$ is the effective fractional diffusion coefficient, determined taking into account the deposition rate of each fraction; $I(\rho_i)$ is the source function, due to the transition of particles from one conditional phase to another, namely, from suspension to the layer of sediment. The appropriate control equation reads:

$$\frac{\partial \rho}{\partial t} = D_{eff} \frac{\partial^2 \rho}{\partial y^2} + I(\rho) \tag{2}$$

In order to describe process in the case of a continuous particle size distribution function $f(d)$ the following average diffusion coefficient can be used:

$$D_{eff} = \frac{1}{\bar{\rho}} \int_d D_{eff}(d) \rho(d) f(d) d(d) \tag{3}$$

According to [26], the conditional driving force of the sedimentation process can be represented in the form of a gradient law:

$$F_{sed} \sim \frac{\partial \rho}{\partial y} = k\rho\left(\rho - \rho^*\right) \tag{4}$$

In order to match the gradient law with the diffusion relation it shoud be assumed that the source function $I(\rho)$ becomes zero at some hypothetical intermediate suspension density $0 < \rho_s < \rho^*$ corresponding to the density of high concentrated suspension nearby the interface between suspension and sediment [26]. In this zone the rates of different fractions sedimentation are almost the same [27]:

$$I(\rho) = -\gamma\rho(\rho - \rho_s)\left(\rho - \rho^*\right) \tag{5}$$

It should be noted that additional studies will be required to assess the impact of the accuracy of determining the parameters of the distribution function on the errors in calculating the kinetics of sedimentation and the dynamics of the sedimentation front. A somewhat different approach is developed in this paper to create a sedimentation model in flow-through devices. The new model is based on the following assumptions:

1. First, it is possible to clearly identify a certain finite number of fractions that differ in order, i.e. in size.

2. Secondly, it is assumed that the composition of the dispersed phase is homogeneous, i.e. all particles of the solid phase carried away by the flow consist of one substance.

3. Thirdly, the partial concentration of the solid phase is not too high. Then, the mutual influence of different fractions on the intensity of their sedimentation can be neglected. Note that this assumption is not critical, and the model built further can be developed without this assumption. However, in this work, such an assumption is made to facilitate a clear description of the structure of the novel model. Some considerations on this issue are given below in the work.

4. Fourth, it is assumed that the shape coefficients of different particles do not differ significantly. Thus, it is possible to accept a uniform dependence of both the coefficient of particle entrainment by the flow and the parameters that determine the settling rate of particles on the order of particles, i.e. on their characteristic size.

5. Fifthly, the distribution of particles of various fractions at the entrance to the apparatus is assumed to be uniform over the entire inlet cross-section. Thus, the partial distribution function in each local region of the input section is the same.

From the five main premises highlighted above, in turn, the provisions of the concept for constructing a model follow: Its own deposition front can be constructed for each fraction. This follows from first, third and fifth assumptions. The second and fourth assumptions make it possible to use uniform calculated dependencies for calculating deposition fronts of various fractions.

Problem statement and model concept.

1. In the stationary mode, there are formed certain curves, which can be denoted as fraction clarification or sedimentation fronts [28].

2. There is a fraction whose extreme clarification front extends from the initial cross-section to the lower point of the final cross-section of the through-flowing apparatus. This front denotes the finest fraction of those particles that are completely deposited along the apparatus and do not fall into the suspension flow leaving the apparatus $r_1 > r_2 > r_3 > r_4 > r_5$. The plot C_3 is shown in Figure 1.

3. The clarification fronts of finest fractions do not end at the lowest point of the apparatus. Therefore, particles of such fractions leave the apparatus together with a flowing stream.

4. Let the symbol $C_{i_{cr}}$ denotes the front of clarification of the critical fraction (i.e., the finest of the fractions that are completely deposited in the volume of the apparatus and are not represented in the flow leaving the apparatus).

5. Thus, the breakthrough of a fraction of order $i \le i_{cr}$ into the flow leaving the apparatus occurs in the "band" between the two boundary deposition curves (Fig. 2): C_i^f and C_i^0. The lower boundary curve C_i^0 for a given fraction *i*represents the trajectory of a particle of this fraction, entering the working volume of the apparatus at a certain point below the upper left point and exiting the apparatus at the lower right point of the outlet section.

6. Let the symbol $C_{i_{\min}}$ denotes the front of clarification of the finest from all fractions in the mixture. Then the average concentration of any fraction from the interval $i_{\min} \le i \le i_{cr}$ at the outlet of the apparatus for the case of a discrete distribution of fractions uniform over the inlet section can be described by the formula

$$\left\langle C_i^f \right\rangle = \frac{S_i^0 C_i^0}{\sum_{j=i_{\min}}^{i_{cr}} C_j^0 S_j^0} \tag{6}$$

7. If, in addition, the rate of sedimentation of the fractions weakly depends on the distance to the lower wall (bottom) of the apparatus, and it depends on the fraction order only, then the sedimentation fronts will be straight lines. Then the previous formula can be rewritten as:

$$\left\langle C_i^f \right\rangle = \frac{S_i^f C_i^0}{\sum_{j=i_{\min}}^{i_{cr}} C_j^0 S_j^f} \tag{7}$$

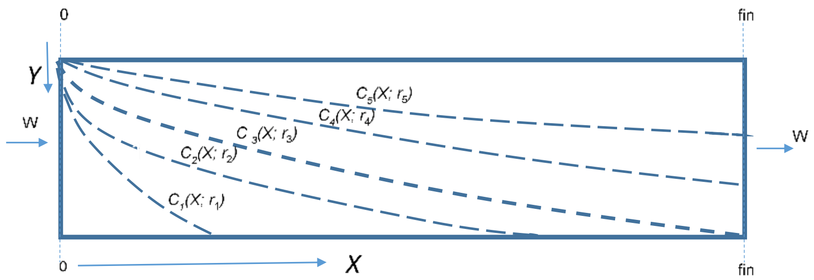


Fig. 1. Typical plots for the boundary deposition curves

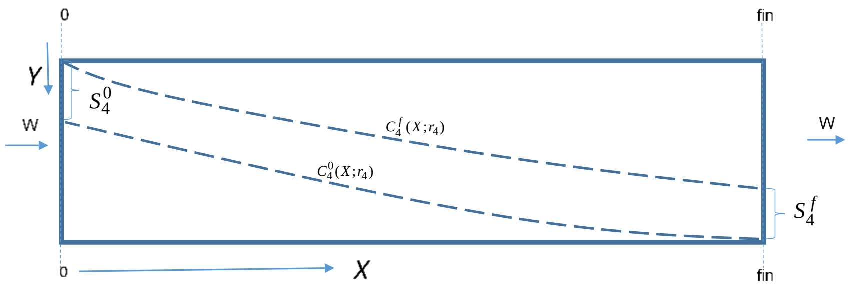


Fig. 2. Typical plots for the top and bottom deposition curves applying to given particle order

This assumption can be more or less acceptable for low-concentration dispersions.

Model analysis and discussion. According to [26**]** without fractions aggregation the problem solution can be look for in the form of a traveling front with a certain speed W_f **:**

$$W_f = \frac{ds}{dt} = -\frac{(\partial\rho/\partial t)_s}{(\partial\rho/\partial s)_t} \tag{8}$$

where s is the position of the suspension front.

With the help of self-similar variable $\eta = s - W_f t$ equation (5) can be rewritten as:

$$D_{eff}\frac{d^2\rho}{d\eta^2}+W_f\frac{d\rho}{\partial\eta}+I(\rho)=0 \tag{9}$$

Then (6) can be rearranged as follows:

$$\frac{d^2\rho}{d\eta^2}=2k\rho\frac{d\rho}{d\eta}-k\rho^*\frac{d\rho}{d\eta} \tag{10}$$

From (6), (7), it follows:

$$\frac{d^2\rho}{d\eta^2}=k^2\rho\left(\rho-\rho^*\right)\left(2\rho-\rho^*\right) \tag{11}$$

From the compatibility conditions of relations (4), (6) and (7) it follows [19]:

$$k=\sqrt{\gamma/\left(2D_{eff}\right)} \tag{12}$$

Here, the following relation is correct [26]:

$$W_f=\sqrt{2D_{eff}\gamma}\left(\frac{\rho^*}{2}-\rho_s\right) \tag{13}$$

As a result, we obtain the equation for describing the suspension density in moving coordinate system:

$$\frac{d\rho}{d\eta}=\sqrt{\frac{\gamma}{2D_{eff}}}\rho\left(\rho-\rho^*\right) \tag{14}$$

Program algorithm.

1. Each subsequent movement of the particle is calculated based on its previous position. For each step, we use the particle's current coordinates (u[i-1] and v[i-1]) to calculate the next coordinates.

2. Direction selection: At each step, a random change is generated for horizontal (du) and vertical (dv) movement. These values can be -1, 0, or +1, which corresponds to moving left, staying still, or moving right horizontally, and similarly up, staying still, or down vertically. The movement of a particle inside a rectangle measuring 500 by 100 cells. The particle starts its path from the uppermost left corner and moves as follows: vertical component + horizontal component. The graph shows each step of the particle, and the Y-axis is inverted to visually correspond to the movement starting from the top corner.

Main code fragment on language Python:

```
Def simulate_particle_movement(rows, cols, r, ug, v0, u0, num_steps=500):
    x, y = u0, v0  # Start at initial positions
    path = [(x, y)]
    horizontal_steps = 0
    vertical_steps = 0
   for _ in range(num_steps):
       dv = random.choice([-1, 0, 1])  # Vertical step
```

```
    du = random.choice([-1, 0, 1])  # Horizontal step
  v = max(0, min(rows+1, y + r + dv))  # Ensure v stays within bounds
  u = max(0, min(cols+1, x + ug + du))  # Ensure u stays within bounds
  if dv != 0:
  vertical_steps += 1
  if du != 0:
  horizontal_steps += 1
  path.append((u, v))
    x, y = u, v
 print("Horizontal Steps:", horizontal_steps)
 print("Vertical Steps:", vertical_steps)
 return path
```

Research results and discussions. Below the results of an analysis applying to the model of sedimentation into the vessels have been submitted. In the case of the constant effective diffusion coefficient and parameter γ, the solution of Eq (14):

$$\rho = \frac{\rho^*}{2}\left[1 - \mathrm{th}\left(\frac{1}{2}k\rho^*\eta + \ln\left(\frac{\rho_0}{\rho^*}\right)\right)\right] \tag{15}$$

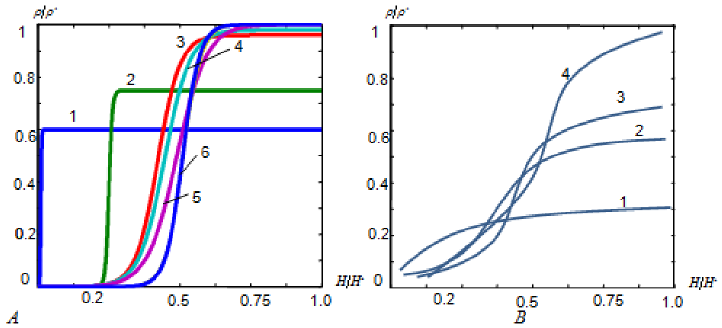
Replacing the self-similar variable η, (15) can be transformed as follows [26]:

$$\rho = \frac{\rho^*}{2}\left[1 - \mathrm{th}\left(\frac{1}{2}\sqrt{\frac{\gamma}{2D_{eff}}}\rho^*\left(s - W_f t\right) + \ln\left(\frac{\rho_0}{\rho^*}\right)\right)\right] \tag{16}$$

Thus, the main novel solution of the submitted diffusion model reads:

$$\rho = \frac{\rho^*}{2}\left[1 - \mathrm{th}\left(\frac{1}{2}\sqrt{\frac{\gamma}{2D_{eff}}}\rho^*\left(s - \sqrt{2\gamma D_{eff}}\left(\frac{\rho^*}{2} - \rho_s\right)t\right) + \ln\left(\frac{\rho_0}{\rho^*}\right)\right)\right] \tag{17}$$

The main results of numerical experiments according to the diffusional model are depicted in Figure 3.

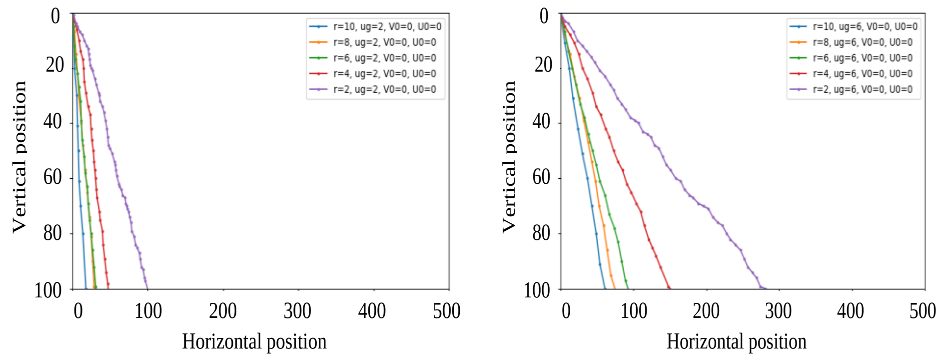


A – main results [26] according to Eq.(17); dimensionless time variable $\tau = tD_{eff}/H^2$: *1* – $\tau = 5$; *2* – $\tau = 10$; *3* – $\tau = 15$; *4* – $\tau = 20$; *5* – $\tau = 25$; *6* – $\tau = 35$; *B* – main data for water suspension of wolframite particles with medium diameter of 2 mm [1].

Fig. 3. Typical time evolution plots of suspension density with height

The initial state of the suspension is represented as a density $\rho_0 / \rho^* = 0.65$ uniformly distributed over the height [26]. The patterns observed in the numerical experiment are in a good agreement with the known experimental data [1].

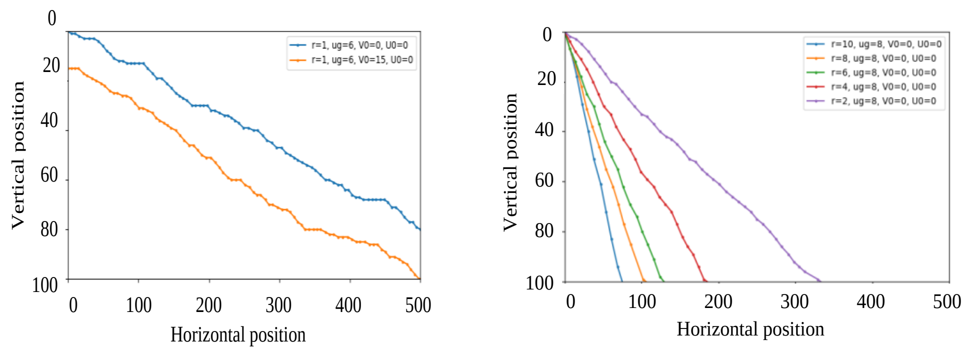
Below the main previous results of an analysis applying to the model of sedimentation into the through-flowing apparatuses have been submitted (Fig. 4, 5).



A *B*

A – Conventional horizontal entraining velocity U_g=2; *B* – Conventional horizontal entraining velocity U_g=6.

Fig. 4. Typical boundary deposition curves in through-flowing systems for different entraning velocities



A *B*

A – Conventional particle order r=1 for conventional entraining velocity U_g=6; *B* – Various conventional particles orders for horizontal entraining velocity U_g=8

Fig. 5. Typical boundary deposition curves in through-flowing systems for different particles orders

Conclusion. The models submitted in this paper give the possibility for calculating the sedimentation characteristics of polydisperse suspensions required for engineering methods applying to two fundamental cases, namely: both for sedimentation in vessels and for this process in through-flowing systems. The data obtained as a result of the model analysis and numerical experiments are in good agreement with the known experimental data. A fairly simple and effective program code has been developed for a novel sedimentation model in a flow system. The use of the developed models will allow for calculating the sedimentation kinetics with other various initial data. For reliable practical application, this model will require further research in order to identify the control parameters for specific physicochemical systems.

References

1. Burt, R.O. Gravity concentration methods // Mineral processing design. – Dordrecht: Springer Netherlands, 1987. – 106-137 p.
2. Bürger R., Concha F., Tiller F.M. Applications of the phenomenological theory to several published experimental cases of sedimentation processes // Chemical Engineering Journal, 2000. Vol. 80. P. 105-117.
3. Bürger R., Karlsen K.H., Towers J.D. Mathematical model and numerical simulation of the dynamicsof flocculated suspensions in clarifier–thickeners // Chemical Engineering Journal, 2005. Vol. 111. P. 119-134.
4. Chebbi R. Non-Colloidal Batch Sedimentation // Journal of Chemical Engineering of Japan, 2007. Vol. 40 (12). P. 1031-1035.
5. García M.H. (Ed) Sedimentation Engineering, Processes // Measurements, Modeling, and Practice, ASCE Manuals and Reports on Engineering Practice, 2007. P. 110.
6. Hernando L., Omari A., Reungoat D. Experimental study of sedimentation of concentrated mono-disperse suspensions: Determination of sedimentation modes // Powder Technology, 2014. Vol. 258. P. 265-271.
7. Kondrat’ev A.S., Naumova E.A. Calculation of the velocity of obstructed settling of monodisperse solid particles in a newtonian liquid // Theoretical Foundations of Chemical Engineering, 2004. Vol. 38 (6). P. 586-591.
8. Kondrat’ev A.S., Naumova E.A. Calculation of the Hindered Settling of a Bimodal Mixture of Solid Particles in a Newtonian Liquid // Theoretical Foundations of Chemical Engineering, 2007. Vol. 41 (2). P. 228-232.
9. Lee K., Kim T., Rajniak P., Matsoukas T. Compositional distributions in multicomponent aggregation // Chemical Engineering Science, 2008. Vol. 63. P. 1293-1303.
10. Lippert M.C., Woods A.W. Experiments on the sedimentation front in steady particle-driven gravity currents // Journal of Fluid Mechanics, 2020. Vol. 889. P. A20(1)-A20(20).
11. Maki R., Tabe Y., Yamamoto T., Takemura H., Sawada T., Esaki T., Ohsaka A. Accuracy study of a novel alternate method measuring erythrocyte sedimentation rate for prototype hematologyanalyzerCelltac α+ // International Journal of Laboratory Hematology, 2021. Vol. 43 (4). P. 588-596.
12. Massah M., Khamehchi E., Mousavi-Dehghani S. A., Dabir B., Tahan H. N. A new theory for modeling transport and deposition of solid particles in oil and gas wells and pipelines // International Journal of Heat and Mass Transfer, 2020. Vol. 152. P. 119568.
13. Mitchell P.J., Spence M.A., Aldridge J., Kotilainen A.T., Diesing M. Sedimentation rates in the Baltic Sea: A machine learning approach // Continental Shelf Research, 2021. Vol. 214. P. 104325.
14. Nocoń W. Quantitative monitoring of batch sedimentation based on fractional density changes // Powder Technology, 2016. Vol. 292. P. 1-6.
15. Pavlenko I., Ochowiak M., Agarwal P., Olszewski R., Michalek B., Krupińska A. Improvement of mathematical model for sedimentation process // Energies, 2021. Vol. 14 (15). P. 4561.
16. Schleiss A.J., Franca M.J., Juez C., De Cesare G. Reservoir sedimentation, Journal of Hydraulic Research, 2016. Vol. 54 (6). P. 595-614.
17. Taye M.A. Sedimentation rate of erythrocyte from physics prospective // The European Physical Journal E, 2020. Vol. 43 (3). P. 19-25.

18. Wallwork J.T., Pu J.H., Kundu S., Hanmaiahgari P., Pandey M., Satyanaga A., Khan M.A., Wood A. Review of Suspended Sediment Transport Mathematical Modelling // Fluids, 2022. Vol. 7. P. 23.
19. Zaslavskiî G.M., Sagdeev R.Z., Usikov D.A., Chernikov A.A. Weak chaos and quasi-regular patterns // Cambridge Nonlinear Science Series, Cambridge, 1992.
20. Berzi D., Fraccarollo L. Intense sediment transport: Collisional to turbulent suspension // Physics of Fluids, 2016. Vol. 28 (2).
21. Xoshimov S., Atakulov D., Yalgashev O., Komilov S., Boykulov J. Evaluation of sedimentation of water reservoirs with modern technologies // In E3S Web of Conferences, 2023. Vol. 365. P. 03033.
22. Guazzelli É., Hinch J. Fluctuations and instability in sedimentation // Annual review of fluid mechanics, 2011. Vol. 43. P. 97-116.
23. Yang A. J., Olsthoorn J., Timmermans M.L. Sedimentation in particle-laden flows with and without velocity shear // Physics of Fluids, 2023. Vol. 35 (8).
24. Wang H., Tai Y., Huang L., Yang C., Jing H. Analyzing Water and Sediment Flow Patterns in Circular Forebays of Sediment-Laden Rivers // Sustainability, 2023. Vol. 15 (24). P. 16941.
25. Hamidifar H., Nones M., Rowinski P.M. Flood modeling and fluvial dynamics: A scoping review on the role of sediment transport // Earth-Science Reviews, 2024. Vol. 253. P. 104775.
26. Brener A., Tazhibayeva B., Golubev V., Dairabay D. Diffusion Model of Polydisperse Sedimentation // Chemical Engineering Transactions, 2023. Vol. 103. P. 733-738.
27. Pfeiffer B.F., de Freitas Dewes M., da Veiga A.B.G. Technological advances in the clinical laboratory: A patent search on erythrocyte sedimentation rate (ESR) devices // World Patent Information, 2024. Vol. 76. P. 102263.
28. Wang K., Yang H., Chang Y., Huang W., Xia J. Phosphorus release and distribution in sediment resuspension systems under disturbing conditions // Chemosphere, 2024. Vol. 142386.

Material received on 26.06.24.

Б.Т. Тажибаева[1], Л.М. Мусабекова[2], А.М. Бренер[1], В.Г. Голубев[1], Л.М. Ульев[3], З.С. Кобеева[1]

[1]М. Әуезов атындағы Оңтүстік Қазақстан университеті, Шымкент қ., Қазақстан
[2]Оңтүстік Қазақстан медицина академиясы, Шымкент қ., Қазақстан
[3]Томск политехникалық университеті, Томск қ., Ресей

ЫДЫСТАРДАҒЫ ЖӘНЕ АҒЫНДЫҚ ҚҰРЫЛҒЫЛАРДАҒЫ СУСПЕНЗИЯЛАРДЫ ТҰНДЫРУДЫ МОДЕЛЬДЕУ

Аңдатпа. Полидисперсті суспензияларды тұндырудың екі жаңа моделі ұсынылған. Бірінші модель ыдыста полидисперсті суспензияны тұндыру үшін жасалған. Бұл модельдегі тәсілдің жаңалығы полидисперсті суспензияны фракциялардың дискретті жиынтығы ретінде емес, бөлшектердің дисперсті фазаның өлшемдері бойынша үздіксіз таралу функциясы арқылы анықтауға болатын жағдайда тұндыру моделін жалпылау болып табылады. Мұны бастапқы терминдермен толықтырылған диффузиялық типтегі теңдеу негізінде жасау ұсынылады. Екінші модель ағынды жүйелердегі полидисперсті суспензияның шөгу процесін сипаттауға арналған. Шекаралық тұндыру қисықтарын құрудың түбегейлі жаңа әдістемесі негізінде аппараттан шығатын ағындағы дисперсті фазаның таралуын есептеу тұжырымдамасы жасалды. Әзірленген модельдер шөгінді фронт пен жауын-шашын бетінің эволюциясын ыдыстың биіктігі бойынша да, ағындық аппараттардың бойлық координаты бойынша да есептеуге мүмкіндік береді. Тұндыру фронттарының

эволюциясын есептеу үшін өрнектер мен компьютерлік бағдарлама жасалды, бұл полидисперсті суспензиялардың тұндыру кинетикасын есептеу үшін маңызды.

Тірек сөздер: тұндыру моделі, полидисперсті суспензиялар, гравитациялық тұндыру, шекаралық тұндыру қисықтары, ағындық жүйелердегі тұндыру.

Б.Т. Тажибаева[1], Л.М. Мусабекова[2], А.М. Бренер[1], В.Г. Голубев[1], Л.М. Ульев[3], З.С. Кобеева[1]

[1]Южно-Казахстанский университет имени М. Ауезова, г.Шымкент, Казахстан
[2]Южно-Казахстанская медицинская академия, г.Шымкент, Казахстан
[3]Томский политехнический университет, г.Томск, Россия

МОДЕЛИРОВАНИЕ СЕДИМЕНТАЦИИ СУСПЕНЗИЙ В СОСУДАХ И ПРОТОЧНЫХ УСТРОЙСТВАХ

Аннотация. Представлены две новые модели седиментации полидисперсных суспензий. Первая модель была разработана для осаждения полидисперсной суспензии в сосуде. Новизна подхода в данной модели заключается в том, что дано обобщение модели седиментации на случай, когда полидисперсную суспензию можно задать не как дискретный набор фракций, а с помощью непрерывной функции распределения частиц по размерам дисперсной фазы. Предлагается делать это на основе уравнения диффузионного типа, дополненного исходными членами. Вторая модель посвящена описанию процесса седиментации полидисперсной суспензии в проточных системах. Разработана концепция расчета распределения дисперсной фазы в потоке на выходе из аппарата на основе принципиально новой методики построения кривых граничного осаждения. Разработанные модели позволяют рассчитывать эволюцию положения фронта седиментации и поверхности осадков как по высоте сосуда, так и по продольной координате проточных аппаратов. Разработаны выражения и компьютерная программа для расчета эволюции фронтов седиментации, что важно для расчета кинетики седиментации полидисперсных суспензий.

Ключевые слова: модель седиментации, полидисперсные суспензии, гравитационная седиментация, граничные кривые осаждения, седиментация в проточных системах.