Chapter 4
Non-Detachment Filtration

ABSTRACT

Rigorous results of a theoretical study of the non-detachment filtration with nonlinear kinetics of suspension absorption and the formation of a gel-like deposit are obtained in Chapter 4. Much attention is paid to the technological aspects of filters functioning under the conditions of intensive accumulation of the non-consolidated and consolidated deposit during the sequence of filter runs to substantiate the service life of the successive replacement of the filter medium material. The technique of the filtration intensification due to a change in the filtration flow during the filter run is proposed and substantiated. The patterns of the suspension filtration with the formation of a surface layer on the packed bed surface under constant rate or pressure drop are established. Theoretical estimation of the effect of the filtration rate (varying many times) on mass transfer and hydraulic resistance of the clogged bed is performed as applied to detachment (Section 3.4) and non-detachment (Section 4.4) filtration.

Mass exchange during the aqueous suspensions filtration on rapid filters is often multidirectional due to the developed significant filtration hydrodynamic force, so that kinetic equations in general case have the form (1.13). At the same time, at a high absorption capacity of filtering material it can be (almost) one-sided and essentially nonlinear. Thus, the suspended solids are actively and firmly fixed on the elements of a packed bed due to the absorption (adhesion) process together with a large amount of bound water and further successfully resist the filtration flow. Then filtration is actually a non-detachable physicochemical process and it is necessary to assume f_{β}=0 in equation (1.13). Sometimes it is allowed to use kinetics and models of the non-detachment filtration and theoretical dependences obtained on their basis also in the presence of an insignificant deposit mobilization.

In the simplest case, the kinetics of impurity deposition is described by a linear equation (Iwasaki, 1937). However, the process of the firm fixation of the dispersed contaminants (irreversible physical sorption applied to the dissolved contaminants) depends on many factors and, first of all, on the concentration of a deposit. Therefore, in order to achieve a plausible description of the process of the contaminant absorption, it is necessary to adopt complex approximation expressions for the single mass exchange coefficient λ. As a rule, it is assumed that the filtration coefficient λ is a function of the concentrations S, S_S and its form should adequately reflect the specific impact of different factors during prolonged filtration.

An exact solution of the corresponding mathematical problem was obtained in Section 4.1 for an arbitrary form of the functional filtration coefficient $\lambda(S)$, which made it possible to take into account such nonlinear effects as the filter ripening (autocatalysis), the limited absorption resource of the filtering material and the bed as a whole. Specific patterns of a change in desired characteristics, inherent exactly

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to the non-detachment type of the filtration process, are revealed at performance of a considerable body of the predictive calculations. The equations intended for the direct calculation of the technological times are presented in a generalized form and for some special cases. The sensitivity of these times is analyzed in relation to the model parameters characterizing the potential capability of a bed and deposit to retain the suspended matter, also the level of the initial contamination of an aqueous suspension.

In view of the regular use in practice only a small part of the absorption capacity of the filter media with predominant deposition of the suspended solids at its inlet section, we studied the non-detachment suspension filtration with a change in the direction of the filtration flow during the filter run. Thus, at the implementation of initially downward filtration, a suspension should be fed into the bed already through its lower surface at the second stage. Quantitative estimation of the results achieved due to a significantly more even distribution of the deposit in the operating volume of the filter has been carried out. They are expressed in a serious reduction in the rate of the head losses increase in the bed being clogged with minimal deterioration of the filtrate quality. In principle, it is possible to noticeably increase the time of continuous effective operation of the filter in this way.

The effectiveness of the surface filtration of essentially heterogeneous suspension was analyzed in detail, which promotes the formation and development of a dynamic filtering layer on the retention surface with a fine perforation. When formulating the corresponding mathematical problem, the mobility of the inlet surface of this layer was taken into account. Two main rate modes of filtration, namely, with a constant rate and at a constant pressure (head) differential at the boundaries of the newly formed incompressible layer, are considered sequentially. The derived dependences are used in the predictive and technological calculations for specific various conditions of filtration.

By analogy with Section 3.4, the role of a hydraulic load in the non-detachment filtration and the possibility to increase the filter productivity by increasing the load were studied. Based on a rigorous solution of the corresponding mathematical problem (Section 4.1), a number of formulas were obtained for calculating the critical parameters and, in particular, the rate V_m, when the filter is initially unable to separate the suspension in the required manner. It should be emphasized that the calculation equations are derived in which the variable filtration rate is already explicitly present and which allow to determine the technological times as functions of it. Using realistic examples, the significance of this rate and parameters characterizing its relationship with the rate of the irreversible immobilization of the suspended matter is studied for the technological process and its parameters.

Finally, the operation of a rapid filter was analyzed in detail for the duration of the service life of a filter media change under particularly unfavorable conditions, when the amount of a non-washable deposit gradually and significantly increases in the sequence of filter runs. Two control algorithms providing different approaches to the determination of the filter run durations with the consolidation criterion are consecutively considered. Suggestions are made for their rational application.

When using the equations of the kinetics of the non-detachment filtration, the choice of a generalized mass exchange rate coefficient (effective filtration coefficient) is problematic in the case of the detachment filtration. Then, in fact, a single coefficient should simultaneously control both components of the interfacial mass exchange, the peculiarities of which differ significantly. From the formal point of view, analytical methods applied to the models of the non-detachment filtration have essentially greater possibilities. And first of all, it was possible to obtain exact solutions for a class of the nonlinear filtration problems reflecting a variety of properties of the filtering material, dispersed impurity, and technological conditions.

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