

Mathematical Modeling of Suspension Filtration on a Rapid Filter at an Unregulated Rate

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Abstract— Mathematical modeling of detachable filtration in the split filter flow mode was carried out using exact and approximate analytical methods. An engineering technique has been developed to determine the duration of filter cycles, based on quality, economic and technical criteria. Determination of rational filter medium height was considered for two materials differed significantly by economic indexes.

Keywords— filtration, modeling, suspension, exact solution, height, split filter flow

I. INTRODUCTION

Clarification of low-concentration aqueous suspensions is currently carried out, as a rule, on rapid filters [1] in two modes - with adjustable (constant) [2, 3] and unregulated (variable) speed. In recent decades, the second mode has been especially widely used in water purification practice [4, 5]. To increase the performance of the filters, they are equipped with special storage tanks, from which the initial suspension is fed to a layer of porous, well-absorbing material (filter medium). Typically, the suspension is fed to the filter at a constant discharge, which significantly exceeds the throughput of a clean and especially clogged medium. Therefore, the specified is discharge distributed between the tank and the filtration stream. With the progressive particles deposition in the medium layer, its hydraulic resistance increases, which accelerates the level rise in the tank. But on the other hand, the piezometric head the inlet to the medium increases, which leads to increased suspension flow and increased output of the filter structure.

II. RESULTS AND DISCUSSION

Mathematical modeling of detachable filtration in the split filter flow mode was carried out using exact and approximate analytical methods. It is based on a complex mathematical model with non-linear effects and variable model coefficients. The assumed model consists of three interconnected compartments – clarification, liquid flow and hydraulic. The clarification compartment describes the transport of particles of the suspension in the medium by the convective mechanism (diffusion one makes an insignificant contribution) and the exchange between the solid (includes the medium elements and the deposit already formed) and liquid phases. The key role in interfacial mass transfer is played by the adhesion of suspended particles to the solid phase. It is the process that directly ensures the removal of dispersed contamination from the aqueous suspension, and its features are reflected in the linear

kinetic equation. It has been established experimentally and theoretically that the most important mass transfer coefficient, namely, the coefficient of suspension particles adhesion rate α , depends significantly on the filtration rate V , and the relationship between them is often almost linear. Then, due to the variability V , both mass transfer coefficients also change with time. Moreover, since the quantity $V(t)$ is initially unknown, the indicated coefficients turn out to be unknown functions of time. Thus, the solution of the second compartment and the corresponding mathematical problem as a whole is much more difficult. Due to the variability V , the second compartment is closely related to the first compartment. It includes the equations of the laminar non-inertia motion (Darcy's law), as well as the equations characterizing the regular increase in the hydraulic resistance of the gradually clogged medium and the composition of the sediment. The latter contains predominantly bound water. The filtration process is determined, firstly, by the permeability of the silty load, and secondly, the suspension level in the tank. The dynamics of this level is described by the equation of balance of the suspension above the working layer. It establishes an equality between the suspension that arrives at the filter, retards in the tank and filtered through the porous medium. At the same time, due to a change in the filtration rate, the pressure losses in the inlet and outlet communications of the filter are also reduced. The corresponding equations are supplemented by the third compartment.

For a particular, but in fact often encountered in practice, case of a linear relationship between α and V , an exact solution was obtained for the correctly posed mathematical problem of filtration in the second mode. The importance of this solution is all the more obvious because, due to the limited changes V at rapid filters, possible nonlinear relationships α with V are suitable for linear approximation. The indicated solution has an integral form and from it follows a set of formulas that make it possible, using standard mathematical analysis software packages, to calculate easily the spatial and temporary changes in the concentrations of suspended and deposited particles of the suspension within the medium layer and at its boundaries, the distribution of head and its general losses in the indicated layer and the transport system of the filter structure, to control the level rise in the tank.

An engineering technique has been developed to determine the duration of filter cycles (time until the next filter backwashing), based on three criteria - quality, economic and technical. The first limits the filtration time due to an excessive

decrease in the protective ability of the medium, the second due to an prohibitive decrease in filter performance, and the third due to overflow of the tank. Dependencies designed to predict the development of the technological process as a whole and its components, to substantiate technological and design parameters are illustrated by many examples with typical initial data. It is shown that in some cases it is advisable to continue filtration even after filling the tank. The analysis of the sensitivity of the filtration characteristics with respect to model coefficients is carried out, which will improve the planning of experimental studies.

Determination of rational filter medium height L was of special attention. Two usual cases with medium material were consequently considered, which differed significantly by economic indexes. In the first case the indicated material from local production wastes is cheap and available in unlimited amount. Then the value L doesn't influence investments and can increase as high as filter run becomes maximal. In the second case the material is of high price because of considerable expenses for transport, preparation and usually its amount is strictly limited. Then such material must be used economically. So, L was varied in technological analysis at constant filter medium volume.

III. CONCLUSION

So an effective tool has been developed for a comprehensive engineering calculation of rapid filters at an unregulated filtration rate, which is a reliable basis for making rational design and technological decisions.

REFERENCES

- [1] A. Tugay, V. Orlov. Water Supply (Vodopostachannia), Kiev: Znannya, 2009.
- [2] V. Polyakov. Filtration of suspensions at the descending rate at linear kinetics of mass exchange. Journal of Water Chemistry and Technology 34 (2), 2012, pp. 65–78.
- [3] A. Tugay, O. Oliynuk, Ya. Tugay. Productivity of water intake well under clogging conditions (Produktyvnist vodozabirnykh sverdlovyv v umovakh kolmatazhu), Kiev: KHAMG, 2004.
- [4] Water Treatment Handbook, 7th Edition. 2 Volume Set. Lavoisier, 2007.
- [5] Alan C. Twort, Don D. Ratnayaka, Malcolm J. Brandt. Water Supply. Fifth Edition. IWA Publishing, 2006.