Research into Clarification Filtration through Synthetic Filtering Partitions

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Abstract. The research presents the results of the study of clarification filtration process of low-concentration sludge suspensions through mixed media filtration systems containing fabric filtering partitions made of synthetic and cotton fibres. It is the kinetics of the clarification process of rougher filtration solutions under study in the research, as well as the stages of the formation of the filtering layer of synthetic filtering partitions are determined; the filtration regime of clarification filtering is analysed; the rate of the increase in the total resistance of the filtering partition in the process of dehydration is evaluated. The data available from the experiments allow providing a mathematical expression for the filtration rate. The influence of structural components of filter fabric on the initial stage of filtration process is taken into account.

1. Introduction

The process of sludge dewatering is often accompanied by collecting filtrate rich in dispersed particles. On the condition that the filtrate consists of valuable dissolved material, it is necessary to decrease the concentration of finely dispersed particles to the required value. It is achieved by subsequent clarifying of the filtrate through the partitions with high retention capacity to block solid particles. For clarification filtration of low-concentration suspensions, the function of separation partitions in clarifying filters is performed by, among other things, cotton filtering partitions consisting of several layers of coarse calico (2-3 layers), or by filter diagonal covered with coarse calico.

An important feature of the filter is a filtering partition, which is its porous base. Common filter fabrics utilized for filtering partitions are made of cotton and synthetic fibres [5].

According to its functions, a filtering partition has to have sufficient retention potential in relation to the processes at the dispersed phase. Filtering partitions have to be characterized by slight hydraulic resistance of filter fabrics and long-life performance (high plugging resistance), etc. [6, 7, 8, 9].

New types of filter fabrics are involved in manufacturing [10,11,12,13]. They are based on fibres with new physical and chemical properties [14,15,16,17,18], which allow increasing plugging resistance by reducing the adhesion forces of sediments to the filtering partition surface, and contribute to regenerating the permeability capacity.
Advances in production techniques contribute to manufacturing filtering partitions with the characteristics to provide a prolonged period of their service [19,20,21,22,23].

Taking into consideration the theoretical and practical importance of addressing the problem of utilizing filtering fabrics as filtering partitions for filters, the kinetics of dehydration process of low-concentration suspensions through filtering partitions made of cotton and synthetic fibres is investigated in the research.

2. Research methods

Testing filtering properties of the partitions in a laboratory environment was performed with a leaf vacuum filter simulator. A filter frame designed as a supporting structure made of metal tubes and covered with filter fabrics served as a filtering component. The supporting structure was attached to the filtration unit through the use of rubber tubing. At the preliminary stage of the experiment the suspension of a specified concentration of solid particles was added to the strainer funnel. The experiment was conducted under the required constant conditions: the temperature of the suspension was 20-22°C, the amount of vacuum was 665 hPa. Over the course of the experiment, test samples of filtrate were being obtained to monitor the amount of suspended solids and the amount of filtrate was being measured over a particular period of time.

The electrophotocolorimeter PhEC-M (ФЭК-М) was employed for analysis of suspended materials concentration in the suspension. The electrophotocolorimeter determined the amount of the filtrate muddiness via its comparison with absorbance of alizarintron solution. When testing filter fabrics with low retention capacity, the muddiness of the filtrate was evaluated by means of weight analysis.

The level of fabric plugging was calculated by finding the value of the force of fabric tear-out per unit area of contact and expressed in g/cm². The adhesive force (adhesion) to the surface of the fabric was measured by an adhesivemeter.

3. Research results

Over the course of the experiment the kinetics of the clarification process of double partitions composed of the following types of fabrics: chlorinated polyvinyl PIN 86006 (backing fabric) and nylon PIN. 56159 (shell fabric), nylon PIN. 56027 (backing fabric) and PIN. 56159 (shell fabric), filter diagonal PIN. 2074 (backing fabric) and fabric PIN 56159 (shell fabric) was studied. It was the cotton filter partition taken as the alternative fabric for a comparative test: filter diagonal PIN. 2074 (backing fabric) and coarse calico (shell fabric).

Filtering properties of double partitions were evaluated by means of the three indicators as exemplified by the filtration process of red sludge suspensions:
- retention capacity in relation to the dispersed phase;
- permeability determined by the filtration rate;
- the level of plugging.

It is found that for all types of partitions there are two periods in the formation of the filtering layer. The first period is characterized by a rapid decrease in the amount of dispersed particles in the filtrate. And the suspension separation coefficient reaches 98.3...99.7. In practical terms, during the first period, the initial filtering layer is formed. By the beginning of the second filtration period, the amount of particles in the filtrate ranges from 0.01 to 0.05%.

The least effective as a filter diaphragm is the use of a synthetic partition made up of fabrics PIN. 86006 and 56159. The amount of the dispersed particles in the filtrate by the beginning of the second period under the conditions is 0.08-1 g/l. Closer behaviour to the standard one of the filter performance is observed in the case of changing coarse calico for nylon fabric PIN. 56159. However, such a partition has a significant disadvantage, since the plugging level of the backing fabric is higher than that of the shell one (the plugging coefficient of the filter diagonal represents four times increase compared to the same indicator for the fabric PIN. 56159).

One of the preferred options for replacing a cotton partition is a partition made up of nylon fabrics PIN. 56027 and 56159. With a slight decrease in the performance compared to all tested samples of
partitions, the combination of these two fabrics provides a high value of the service life coefficient \( S_{LC} = 4.14 \). The data are explained by the relatively low plugging level of both the backing and the shell fabrics.

The research shows that clarification filtration is performed in the filtration mode with gradual plugging of the pinholes. And the following equality is true for the total resistance of the filtering partition:

\[
\frac{dR}{dg} = \frac{X_o}{\pi l k} \sqrt{\frac{\pi \Delta P}{2 \mu l k N n}} R^{3/2}; \tag{1}
\]

where \( X_o \) is the ratio of sediment volume to the filtrate volume, m\(^2\) m\(^{-3}\);
\( l_k \) is the length of the cylindrical capillary, m;
\( \Delta P \) is the difference of pressure nm\(^{-2}\);
\( \mu \) - viscosity of the liquid phase of the suspension, n sec m\(^{-2}\);
\( N n \) is the number of identical cylindrical capillaries;
\( R = R_{oc} + R_{fp} \) – total resistance during filtration, m\(^{-1}\).

In this case, the intensity of the increase in the total resistance as the amount of filters increases is proportional to this resistance in the power of 2/3. Consequently, the total resistance of the partition increases less intensively than when filtering with complete blockage of the pinholes [1].

The following expression is valid for filtering speed:

\[
W=W_{ini} \left[ \frac{1}{2 \pi l k} \sqrt{\frac{\pi \Delta P}{2 \mu l k N n}} \right] \cdot \frac{1}{\left(\frac{W_{ini}}{q}\right)^{1/2}} q \right]; \tag{2}
\]

where, \( W_{ini} \) – initial filtration rate, m\(^3\) m\(^{-2}\) sec or m sec\(^{-1}\);
\( q \) - the volume of filtrate obtained from 1m\(^2\) of the filtration surface, m.

At the initial moment of clarification filtration, the filtration rate is determined by the main elements of fabric structure [2]. The following equalities are valid for \( W_{ini} \):

Case 1: the pinholes of the filter fabric are in warp direction:

\[
W_{ini}=\frac{\beta (1-d_0 Z_o) \left(1-d_y Z_y\right) \eta \lambda \alpha^2}{Z_o^2 (d_0+d_y) \eta o}; \tag{3}
\]

Case 2: the pinholes of the filter fabric are in weft direction

\[
W_{ini}=\frac{\beta (1-d_0 Z_o) \left(1-d_y Z_y\right) \eta \lambda \alpha^2}{Z_y^2 (d_0+d_y) \eta o}; \tag{4}
\]

Case 3: the filter fabric is characterized by the presence of isodiametric quadratic pinholes:

\[
W_{ini}=\frac{\beta (1-d_0 Z_o) \eta \lambda}{2 d_0 Z_o^2 \eta o}; \tag{5}
\]

where, \( d_0 \) and \( d_y \) are the thread diameters of the warp and weft, respectively;
\( Z_o \) and \( Z_y \) – the number of threads per 1 cm, the warp and weft, respectively;
\( \lambda \) - the coefficient of roughness;
\( \eta \) – liquid viscosity;
\( \beta \) – coefficient equal to \( 8.1 \times 10^3 \);
\( H \) – pressure loss, kgf/m\(^2\).
4. Conclusion
Thus, after a comparative evaluation of the kinetics of the clarification process of low-concentration suspensions through various types of filtering partitions, the following conclusions can be drawn:

1. clarification filtration of low-concentration sludge suspensions is determined by two periods. The first period is characterized by the formation of an effective section of the partition capillaries (filtering layer), the separation coefficient reaches the value of 98.3 – 99.7. The second period allows the clarification process to be carried out with a sufficient degree of quality (the amount of dispersed particles in the clarified solution is not more than 0.01-0.05 g/dm$^3$).

2. taking into account the feature of fabrics to resist plugging in the process of clarification filtration, it is possible to recommend replacing a cotton combined partition (filter diagonal and coarse calico) with a synthetic one consisting of nylon fabrics PIN.56027 and PIN.56159, which provide a high value of the service life coefficient (K=4.14).

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