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CRITICAL VELOCITIES OF THE COAGULATED WATER FLOW

The formulae for the permissible velocity of water movement, containing flocs suspension in the pipes, have been worked out. At the same time, the character of the flow, value of the velocity gradient permissible for flocculation and roughness of the pipeline were taken into account. The worked out formulae may be applied in designing the devices for the water supply systems.

NOTATIONS

A — constant occurring in [5], $m^{2/3} \cdot s^{-1}$,
d — pipeline diameter, m,
D — energy dissipation, $kG \cdot m^{-2} \cdot s^{-1}$,
G — velocity gradient, s^{-1},
V_d — average permissible velocity of flocky suspension movement in the pipe, $m \cdot s^{-1}$,
η — dynamic viscosity, $kG \cdot m^{-2} \cdot n$,
ν — kinetic viscosity, $m^2 \cdot s^{-1}$,
λ — resistance coefficient.

1. AIM AND SCOPE

Coagulation is a commonly used process in the systems of the surface water purification. It enables the removal of the low rate of suspension sedimentation, colloids, microorganisms and some of the dissolved organic compounds from the water. The achievement of these effects is related to the mechanism and technology of the very coagulation, with the hydraulic conditions in the flocculation chambers, in coagulation tanks, high-rate filters and in the pipelines connecting these devices.

The specification of the technological criteria for pipeline designing for the flocs suspension is still an open problem.

At present, obligatory design recommendations for the pipelines that connect the flocculation chambers, coagulation tanks and high-rate filters refer to the permissible

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velocity of the flow which according to the authors [1-4] — should not exceed the values of 0.3-0.7 m/s. The permissible velocities, according to various authors, are almost constant regardless of the diameter of the pipeline, rouqhness degree of their surfaces, temperature of water and character of its movement. The determination of the influence of these factors on the permissible velocity of the water movement in the pipelines, protecting against the breaking of the floccules and against their sedimentation and in order to formulate the univocal principles of their design, makes up the purpose of this paper.

2. TECHNOLOGICAL CRITERIA FOR DESIGNING THE PIPELINES OF THE FLOCKY SUSPENSION

The average velocity of the flocs suspension movement in the pipelines should protect the flocs against sedimentation and their destruction. The velocity gradient given by CAMP [2, 4], being adequate for the flocculation chambers since the same boundary conditions are required, has been applied to the estimation of the pipe flow hydraulic influence on the behaviour of the flocs:

$$G = \sqrt{\frac{D}{\eta}}. \qquad (1)$$

On the ground of the known Darcy's principle and on energy dissipation notion, with the definition of the velocity gradient, the following equation has been obtained:

$$V_d = \sqrt[3]{2\nu G_d^2 \frac{d}{\lambda}}. \qquad (2)$$

The equation (2) is a general, obligatory solution, regardless of the kind of the liquid movement, its viscosity, diameter of the pipeline and its surface roughness. The particular solutions depend on the accepted form of the function $\lambda = \lambda\,(\mathrm{Re}, k/d)$. The value of the velocity gradient G_d depends on the physical characteristics of the flocs and should be determined experimentally, separately for each technology of the purification. Polyelectrolytes that strengthen the structure of the floc have the essential influence on the value of the permissible velocity gradient.

Under the conditions of the laminar flow, the equation (2) takes the form:

$$V_d = \frac{1}{4\sqrt{2}} G \cdot d, \qquad (3)$$

whereas, for the range of the turbulent flow, determined by the Blasius formula, the true relation is:

$$V_d = \sqrt{6.27 \cdot G^2 \cdot d^{1.25} \cdot \nu^{0.75}}. \qquad (4)$$

The range of applying the relations (3) and (4) is determined by the values of Reynolds numbers equal to 2300 and 80000, respectively, while the equation (2) and the Colebrook-

White formula should be taken for the higher values of Reynolds numbers. The relations (2-4) are the technological criteria for designing the pipeline that transport water and flocky suspension, since they combine the parameters of the pipe hydraulics with the commonly accepted technological parameter characterizing the flocculation.

3. CALCULATION METHODS

The usage of the equations (2-4) in the calculations of the pipeline requires the selection of the gradient value G. In the basic works, the taken values should be justified experimentally. Assuming the analogy between the influence of the turbulence in the pipes and in the flocculation chambers on the structure of the floc, the following gradient values [1-4] may be applied to the design processes:

$G = 25\ s^{-1}$ for sedimentation of the flocs,

$G = 65\ s^{-1}$ for flocculation and hydrotransport of the flocs in the pipes,

$G = 75\ s^{-1}$ for destruction of the flocs structure.

While using the accepted values, the relation (2) has been simplified:

$$V_d = A\sqrt[3]{\frac{d}{\lambda}}, \tag{5}$$

where values of the constant $A = A(T, G)$ are given in table.

Table

The influence of the temperature and velocity gradient on the value of the constant A

Wpływ temperatury i gradientu prędkości na wartość stałej A

T	G		
	$25\ s^{-1}$	$65\ s^{-1}$	$75\ s^{-1}$
275.15 K	0.1308	0.2474	0.2722
283.15 K	0.1178	0.2228	0.2450
293.15 K	0.1079	0.1782	0.2042

Utilization of the relation (3) is restricted to those values of the diameters of the pipes equal to:

$$d \leqslant \frac{0.15}{\sqrt{G}} \tag{6}$$

reffering to the diameters corresponding to the capillaries, which eliminates the possibility of its practical usage in the calculations for the pipes. However, the equation (4) may be helpful in the calculations related to the small diameters of the pipelines:

$$d \leqslant \frac{2}{\sqrt{G}}. \tag{7}$$

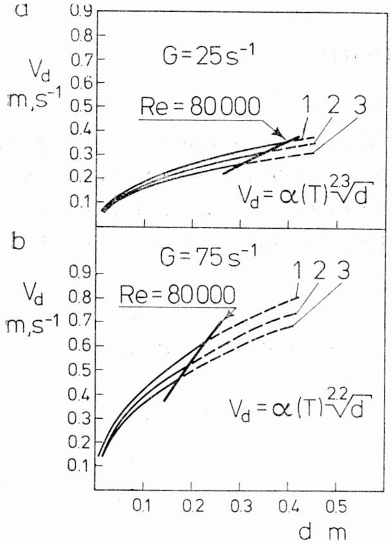

Fig. 1. Curves of the equal velocity gradients in the co-ordinate system V, d for the range of Blasius formula usage

1 — $T = 273.15$ K, 2 — $T = 283.15$ K, 3 — $T = 291.15$ K
a — $\alpha(273.15\ \text{K}) = 0.5480$, $\alpha(283.15\ \text{K}) = 0.5029$, $\alpha(293.15\ \text{K}) = 0.4683$
b — $\alpha(273.15\ \text{K}) = 1.2118$, $\alpha(283.15\ \text{K}) = 1.1182$, $\alpha(293.15\ \text{K}) = 1.0412$

Rys. 1. Krzywe jednakowych gradientów prędkości w układzie współrzędnych V, d dla zakresu stosowania formuły Blasiusa

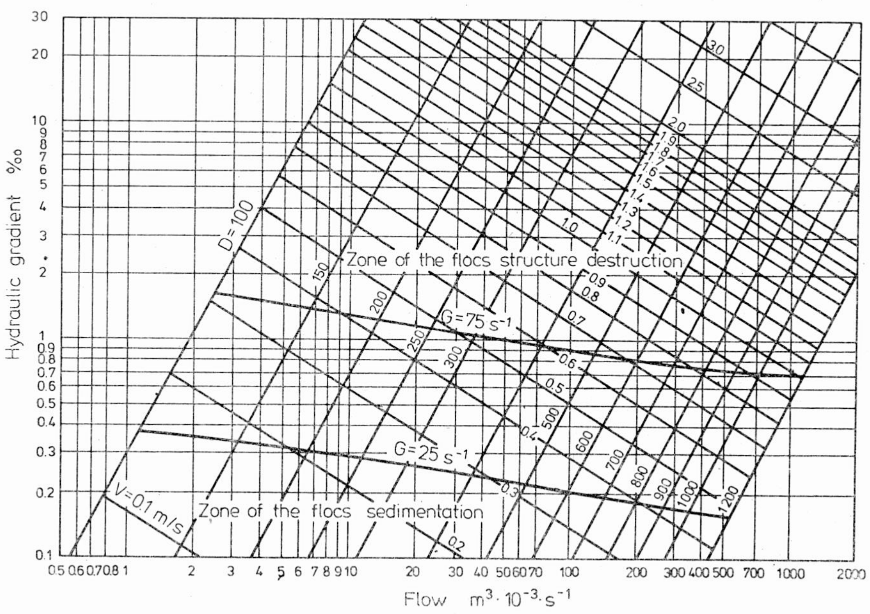

Fig. 2. Curves of the equal velocity gradients in the Colebrook-White monogram system
Rys. 2. Krzywe jednakowych gradientów prędkości w układzie monogramu Colebrooka-Whitea

Values obtained from the equation (4) are presented in fig. 1.

Fig. 2, showing a Colebrook-White monogram with drifted curves of the equal boundary velocity gradiens with the relative roughness of the pipelines equal to 0.4, simplifies the usage of the equation (5) which includes the whole range of the diameters of the pipelines being used in practice.

4. CONCLUSIONS

1. The visible dependence of the diameter of the pipelines on the permissible velocity of the flocs suspension movement in the pipelines is expressed by an increasing function. Temperature of water, character of the movement and roughness of the inside surface of the pipe have also the essential influence.

2. The calculated values of the safe velocity of the flow, especially for the big diameters of the pipelines, differ considerably from those used so far.

3. It is also possible to use the hydraulics of pipe for the flocculation which, in some cases, may bring the essential economic effects.

4. The flocculation phenomena in the pipelines should be analyzed experimentally, both on model and technical scale, and, in order to interpret the obtained results, one may use the theoretically obtained formulae presented in the paper.

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KRYTYCZNE PRĘDKOŚCI PŁYNIĘCIA WÓD KOAGULOWANYCH

W pracy wyprowadzono wzory na dopuszczalną prędkość ruchu wody z zawiesiną kłaczkowatą w rurach. Uwzględniono przy tym charakter ruchu, dopuszczalną dla procesu flokulacji wartość gradientu prędkości i chropowatość rurociągu. Wyprowadzone wzory mogą być stosowane w projektowaniu urządzeń zakładów wodociągowych.

KRITISCHE FLIESSGESCHWINDIGKEITEN VON WASSER WELCHES GEFLOCKTE SCHWEBESTOFFE BEINHALTET

Angeführt werden Formeln der kritischen Fließgeschwindigkeit von Wasser, welches geflockte Schwebestoffe beinhaltet in Rohren. Der Bewegungscharakter, der für die Flockung zulässige Wert des Geschwindigkeitsgradienten und die Wandrauhigkeit des Rohres wurden dabei in Betracht gezogen. Diese Formeln sollten bei der Projektierung von Wasserversorgungs- und Aufbereitungsanlagen angewandt werden.

КРИТИЧЕСКИЕ СКОРОСТИ ТЕЧЕНИЯ КОАГУЛИРОВАННЫХ ВОД

В работе выведены формулы для допускаемой скорости движения воды с хлопьевидной суспензией в трубах. При этом был учтён характер движения, допускаемого для процесса флокуляции, значение градиента скорости и шереховатость трубопровода. Выведенные формулы могут использоваться в проектировании трубопроводных сборудований.