Studies of turbulent flow characteristics of dividing open water streams

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Abstract. The movement of water in the areas of division of open streams has a particularly turbulent character. For a detailed study of river bed processes, it becomes necessary to identify the patterns of turbulent motion [1]–[29].

The aim of these studies was to study and determine the turbulent characteristics of the flow and to establish the relationship between the intensity of flow turbulence with the channel deformations observed.

Theoretical and experimental research methods, laboratory studies, field surveys of existing water intake units were used. When processing the results of experimental studies, the methods of mathematical statistics were used.

On a specially constructed hydraulic model, detailed experimental studies of the flow structure in the fission unit were carried out under conditions of rigid and eroded channels. [3], [28], [29].

Detailed studies have revealed the kinematic structure of the flow in the section of flow division.

The nature of the change in the intensity of the turbulent characteristics of the flow in different sections of the fission unit in rigid and eroded channels is determined.

The relationship between the nature of the change in the flow turbulence intensity and the channel deformations observed in the division unit has been established.

1. Introduction

Analysis of works on hydraulic research of open flow dividing units shows that in the literature little attention is paid to the study of conditions of excessive flow turbulence.

Numerous experiments and observations of the channel flow have shown that the movement of water, especially in the areas where open flows are divided, has a particularly turbulent character. All the processes occurring in the channels depend on the turbulence of the flow, its intensity, and geometric scales. Therefore, for a more complete study of channel processes, it is necessary to know the laws of turbulent motion and the laws connecting the characteristics of turbulence with channel processes. [1].

In view of the complexity of the theoretical study of the problem of turbulence in the general case of non-uniform flow motion, the study of turbulent flows is carried out largely experimentally.

The phenomenon of turbulence can be detected by measuring the flow velocity, when at certain points the device registers the fluctuation (pulsation) of the velocity.
2. Aim of investigations
The aim of these studies was to study and determine the nature of the change in the turbulent characteristics of the flow within the fission unit under the conditions of a washed out and indelible model and to establish the relationship between the nature of the change in the intensity of flow turbulence with the channel deformations observed in the fission unit.

3. Research methods
The authors used theoretical and experimental studies using the equation of changing the momentum, laboratory studies on a hydraulic model, field studies of existing water intake units, as well as an analysis of experimental data available in the literature on this issue. When processing the results of experimental studies, the methods of mathematical statistics were used.

To characterize the pulsating speed, it is necessary to know its mean value and the root-mean-square pulsation deviation [1]. The value of the instantaneous or actual speed at point v is the sum of the average speed \( \bar{v} \) and the fluctuation deviation of the speed \( v' \) from its mean value:

\[
\bar{v} = v + v'
\]  

where: \( \bar{v} \) is the average local speed over a sufficient period of time.

The average instantaneous velocity is taken as the averaged instantaneous velocity over a sufficient period of time \( t \), which is taken as a value that does not cause a change in the velocity \( v \) with an increase in the averaging period \( t \) [2].

In our studies, this interval was 60 seconds.

To assess the turbulence of the flow, the changes in the intensity of turbulence within the section of the flow division unit were analyzed.

The values of the turbulence intensity \( K \) represent the ratio of the standard deviation \( \sigma_v \) of the local instantaneous velocities \( v \) from the average velocity \( \bar{v} \) to the average velocity on the vertical \( v \):

\[
K = \frac{\sigma_v}{v}
\]  

An experimental study of the flow turbulence intensity was carried out on a model setup shown in Figure 1.

4. Research results and discussion
An analysis of the turbulent characteristics of the flows showed that the nature of the change in the value of the turbulence intensity in the section located above the fission unit at a distance of 3B from the upper edge of the water intake is approximately the same as for a uniform rectilinear open flow, namely, the values are within 0.04 \( \div \) 0.05. With immersion into the depth of the flow, its value increases, acquiring its maximum value 0.09 \( \div \) 0.13 at approximately 0.8 h. Then the value of the turbulence intensity drops sharply and at the bottom of the main flow is about 0.08 \( \div \) 0.095 (Fig. 2, a).

In the section located at the fission node, on the flow surface, the \( K \) value varied from 0.042 to 0.086. It should be noted here that the change in the intensity of turbulence on the verticals occurs in different ways. This distribution of turbulence intensity is caused by transverse circulation of the flow. For example, on the vertical near the right bank of the main channel, in this section, the value of \( K \) from the surface of the stream to a depth of 0.6h gradually decreases from 0.086 to 0.06, and then, in the section from 0.6h to 0.8h, it begins to sharply increase to 0.23 and then drops again near the bottom up to 0.16. On other verticals, no sharp jumps in the change in turbulence intensity are observed at this section (Fig. 2, b).

As one moves away from the fission node, the change in the intensity of turbulence on the verticals occurs more smoothly, with the absence of pronounced jumps. Thus, in the section located at a distance of 3B below the division node, the turbulence intensity at the flow surface at all verticals is 0.07. As you descend along the verticals, a gradual increase in the intensity of turbulence is noted at all verticals at the bottom of the main stream. So, on the 3rd vertical the \( K \) value was 0.145, on the 2nd vertical was 0.138 and on the 1st vertical was 0.10.
In the diversion channel, the formation of a whirlpool zone at the beginning of the diversion channel near the left bank has a significant effect. So, in the section located at a distance B from the lower edge of the water intake, there is such a change in the intensity of turbulence, as shown in Fig. 2, c. An increase in the value of the intensity of turbulence is noted in the area of formation of the whirlpool zone, and in the zone of the transit flow, its decrease.

In the outlet channel, the leveling of the turbulence intensity occurs at a large (5 - 6B) distance from the beginning of the water intake. This is influenced in a certain way by the vortex zone formed at the initial section of the diversion channel.
Figure 2. Turbulence intensity change graphs
5. Conclusions

1. On a specially constructed hydraulic model, detailed experimental studies of the flow structure in the fission unit were carried out under conditions of rigid and eroded channels.

2. By conducting detailed studies, the kinematic structure of the flow in the section of flow division has been revealed.

3. The nature of the change in the intensity of the turbulent characteristics of the flow at different sections of the fission unit in rigid and eroded channels has been determined.

4. Analysis of the turbulent characteristics of the flows showed that the nature of the change in the value of the turbulence intensity in the section located above the fission unit at a distance of 3B from the upper edge of the water intake is approximately the same as for a uniform rectilinear open flow, namely, the values are within 0.04 ± 0.05. With immersion into the depth of the flow, its value increases, acquiring its maximum value 0.09 ± 0.13 at approximately 0.8 h. Then the intensity of turbulence drops sharply and at the bottom of the main stream is about 0.08 ± 0.095.

5. In the diversion channel, the formation of a whirlpool zone at the beginning of the diversion channel near the left bank has a significant effect. So, in the section located at a distance B from the lower edge of the water intake, there is such a change in the intensity of turbulence, as shown in Fig. 2, c. An increase in the value of the intensity of turbulence is noted in the area of formation of the whirlpool zone, and in the zone of the transit flow, its decrease.

6. In the outlet channel, the leveling of the turbulence intensity occurs at a large (5 - 6B) distance from the beginning of the water intake. This is influenced in a certain way by the vortex zone formed at the initial section of the diversion channel.

7. The relationship between the nature of the change in the intensity of the flow turbulence and the channel deformations observed in the division unit has been established.

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