Studies of Structures of Gates in Hydraulic Engineering

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Abstract. The article reveals the complex nature of the gates provided in water discharge installations of hydropower units to adjust the flow of water into the downstream bay. There are strict requirements for their reliable and safe work, for gaining the complete culvert closure and allowing passing a calculated water flow during the flood period. In order to more efficiently implement these requirements, technical solutions on the improvement of the shutters’ design are constantly developed. The results of studies of such new structures are given. The task of the present research is to identify the most common approaches to shutter improvement. In the result of the study, the following most widespread methods of improving shutters design are identified: 1) development of efficient geometric forms of shutters and their parts; 2) development of efficient design of the auxiliary elements of shuttering devices; 3) increase of dynamism degree for the structural elements of the shutter; 4) parts size reduction, repeated use of smaller elements. Examples of these methods are provided. The results of this research are recommended for use at practical activities to further improve the gate of hydraulic structures.

1. Introduction

Currently, a large number of hydraulic units are operated in Russia. In most cases, these are complex objects serving to satisfy the needs of various water users. At the same time, all the structures of hydropower units that provide water damming at river objects and creation of reservoirs include necessarily in their system composition such water supply structures which regulate the water flow to be passed to a downstream bay and are equipped with mechanical equipment with shutter devices [1, 2].

Generally shutter devices include a plurality of complex interrelated elements. The main one is a shutter itself. Besides, additional (auxiliary) elements are usually related to a shuttering device, without which the shutter can not perform its functions: ensure reliable overlapping of a discharge opening for a long time, to pass a certain water flow in a given period of time, to provide an possibility to terminate the passage of water for a required short period of time, etc. Such elements are grooves, embedded elements that are built in piers, running gear, support rails (strips), loading elements, trolleys for maneuvering a gate, pickup (clutch) devices, supports, bypass elements, seals, etc. [3, 4]. The shutter and the above-mentioned additional (auxiliary) elements must comply with the requirements of strength, operation reliability and ensure favorable hydraulic conditions when the water flow is passing.
The accumulated long-term experience of operating hydraulic structures gates, the results of numerous on-site and laboratory research on their operation, as well as achievements in the field of new materials, equipment and technologies [5, 6] give rise to the development of these complex technical systems and their upgrade in constructive, technological and functional ways. The relevance of this development is confirmed by achievements in new developed solutions to improve the accuracy of constructive forms, to reduce the amount of used high cost materials, to increase the technological quality of the work in their production, finally leading to the reduction of the cost of the shutter. It is also important to increase in the reliability and safety of their operation, improving personnel working conditions [7, 8].

2. Materials and Methods
The object of the study in this paper was flat surface and deep gates of hydraulic structures. The subject of the study is the methods of improving the structures of the gateways of hydraulic structures.

The aim of the study is the analysis of technical proposals on constructive solutions upgrade for flat shutters of hydraulic structures and identifying the most effective and promising methods for their improvement for practical implementation in specific facilities. Research techniques are analyzing patented technical developments and proposals for hydraulic flat shutter structure improving, generalizing the data and identifying the most common methodological approaches used to ensure requirements for hydraulic structure flat shutters, as well as working out recommendations for the use of identified methods for further development of shutter design in hydrotechnical construction. In the studies, the Russian Federation patent database patents was used.

3. Results and discussions
The analysis showed that at present due to scientific and technological progress and the development of new materials and technologies there has appeared a wide range of opportunities for improving the constructive solutions of such complex mechanical equipment structures as gate devices with flat shutters [9].

A.V. Karavayev and B.G. Cartelev [9] propose for overlapping the surface water passage openings at river hydraulic structures to use a more effective shutter shape, the bearing structure of which is made in the form of an arch. The arch is placed horizontally, and its supports are made in the form of rigid beams based on the grooves of the piers (figure 1). Such a design will ensure a reduction in the weight of the shutter, and therefore the decrease in the required load capacity of the lifting crane. The above example can be attributed to one of the most common methods of improving the shutter devices, the essence of which is to develop effective geometric shapes and outlines of the main elements of the shutters and their parts, rationalizing the size of the elements bearing structures and the balance between them. We shall assume this approach as the first method (way) for improving hydraulic unit gateway structures.

The same method is used in the design of a flat shutter of water discharge plant by S.A. Zazhigalin, A.V. Zharov and A.K. Marishkin [9]. The shutter includes a vertical frame and a regulating board with vertical and horizontal stiffeners. The casing of the regulating board is proposed to be made in the form of a single channel shaped bed (figure 2).

The advantage of the proposed design is in reducing the materials amount adjusted with welding. In addition, due to a decrease in a number of parts, its manufacture simplifying is achieved.

A lot of constructive solutions have been developed and patented on additional (auxiliary) elements of shutter devices., in our opinion, it is expedient to unite such solutions as the second method (way) of improving shutter devices : namely the development of efficient designs for shutter additional (auxiliary) elements, optimization of their forms and sizes.

The typical example of this method is the depth waterway shutter design by V.P. Butin [9]. Here it is proposed to upgrade shutter support and movement parts. O achieve the effect, each lateral support
and gear assembly node is proposed to be made in the form of a corner (figure 3). This constructive solution is intended to improve the reliability of a flat shutter.

Figure 1. View of hydraulic gate [A.V. Karavayev and B.G. Cartelev]: 1 - bearing element of shutter unit, 2 - casing, 3 - support rigid beams, 4 - piers, 5 - piers hinge elements

Figure 2. Flat surface shutter [SA. Zazhigalin, A.V. Zharov and A.K. Marishkin]: 1 - regulating board, 2 - channel shaped bed.
We can offer, as another illustration of this second upgrade method, an automatic coupling for multisection water deep and bottom shutters by P.N. Kovalenko, described in [9]. This device is recommended to be used for coupling multi-sectional gates used at the hydraulic units. The essence of the proposed solution is to perform a coupling in two links: an upper one and a lower one. In this case, the housing of the upper coupling is made bell-shaped. The bottom link casing has a large and a small supporting and hooking extensions. The design of the coupling will ensure an increase in the reliability of the shutter lifting mechanism. A.M. Tiguntsev and V.G. Gubanov [9] developed a shutter drive, which also can be referred to this method. The drive is designed to lift and lower a flat shutter. The specific feature of this constructive solution is that the shutter hydraulic cylinder is placed on the bearing frame along with the controlled pickup. The pickup provides fixing of the hydraulic cylinder. The technical achievement of this solution is increasing the repair accessibility to the device elements and reliability of the shutter operation.

A typical example of the second method is the development of a surface anti-ice coating by N.V. Ushakov, B.V. Buravlev, V.N. Baranov, O.S. Zaremba and V.N. Khodzhaev [9]. The coating is recommended to be used in the grooves of flat shutters, made in the water intake unit of a hydraulic structure. Coatings plates made of polymer material have an increased line extension coefficient and are fixed in the of the supports grooves (figure 4). A positive effect of this solution is in reducing damage from icing due to removing the ice built up while slabs temperature compression and expansion.

**Figure 3.** Forms of grooves for flat deep hydraulic shutter [V.P. Butin]

**Figure 4.** Grooves of flat shutter with coating [N.V. Ushakov, B.V. Buravlev, V.N. Baranov, O.S. Zaremba and V.N. Khodzhaev]: 1 - support of hydraulic structure, 2 - gate groove, 3 - upper coating plate, 4 - lower coating plate.
The upgrade of complex structures is often achieved through increasing the degree of dynamism of constituent structural elements. With regard to the shutters it is made by using movable to each other elements, flexible parts, elastic shells. V.V. Efremov and G.A. Rogovoy [9] used this very method in their development. The locking device of the waterway header includes a flat shutter, made in the form of two shields with wedge edges on the sides (figure 5). To overlap the waterway opening, the inner shield first goes down, sets on the base and stops. The external shield continues to move down and then both shields are fixed in the grooves. Such a design will ensure an increase in operational reliability of the shutter unit and reduce the filtration (leakage) of water when the shutter is closed.

Figure 5. Flat shutter with two shields [V.V. Efremov and G.A. Rogovoy]: 1 - internal shutter shield, 2 - external shutter shield, 3 - drive, 4 - supporting protrusions, 5 - wedge-like edges.

Similar solutions could be united as the third method (way) of gate improvement - increase the dynamism degree of structural elements of the shutter by using movable to each other elements, flexible parts, elastic shells.

The fourth method (way) of gate upgrade can be formulated as chipping of the design, the use of repeated elements, diminishing the size of shutters structural parts and (or) of their elements.

As an example for this method, one can consider a shutter device of the open water way by L.S. Khasenevich [9]. The shutter unit is proposed to be provided with additional pairs of widths with guiding platers (figure 6). Thus, the shutter unit is formed by a plurality of shutter widths. The developed device will perform its main functions at a larger range of water pressures and it allows to simplify the design of the shutter unit.
This same method is used by N.P. Vershinin and I.N. Vershinin [9] in the device for overlapping open flows. In this technical solution, the regarded part of the river bed is blocked up with separate shields crossing the river from one bank to the other (figure 7). At the same time, a number of sequentially installed shields form a sections isolated from each other, at which it is feasible (convenient) to perform individual independent types of work on bottom cleaning.

The completed research and systematization of technical solutions that improve the feasibility and economic parameters for flat shutters of hydraulic structures, indicate that these complex technical systems are constantly being developed and improved. The formulated here basic methods for improving the structures of gate devices will allow to use them for the expedient selection of the way to further improve main bearing elements and the shutter unit itself as a whole, increasing the reliability and safety of their operation.

These ways can be considered to be universal. They can be used to improve any other complex technical devices and structures, for example, dams [10]. At the same time, the most important task is the use of new solution into specific projects.

4. Conclusions
The main conclusions of the present research are as follows:
1. The shutter designs of hydraulic structures are constantly being improved because of appearance of new requirements related to increased reliability and safety of work, as well as in connection with the use of new materials and technologies.

2. Main ways of improving flat shutters designs could be formulated in the terms of four following groups: 1) development of efficient geometric shapes and outlines of the main elements of shutters and their parts, rationalization of the size of bearing structures elements and the relations between them; 2) development of efficient designs for additional (auxiliary) elements of shutter devices, rationalization of their forms and geometric sizes; 3) increase of dynamism degree of the structural shutter structural elements by using movable elements with affordable, flexible parts, elastic shells; 4) design chipping, repeated use of the same elements, diminishing the size of shutters structural parts of the shutters and (or) of their elements.

3. The formalization of methods for improving the structures of hydraulic structures gateways will intensify the improvement of their operational parameters.

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