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Influence of swirler construction to the "oblique waves" occurrence

The paper considers the modes of tangential swirl spillway of the Medeo antimudflow dam. Experimentally proved that the "oblique waves" effect in the initial part of the shaft spillway occurs due to "overlapping" streams of water flow in the tangential swirler. This effect can be eliminated by improving the design of the swirler. The methods of three-dimensional computer modeling and animation were used to calculate and analyze the impact of structural elements of the swirler on the occurrence of "oblique waves" depending on the angle of the bottom shelf of the tangential swirler. A simple and effective design solution based on the example of the Medeo dam provides a rapid transition from the spatial structure of the water flow to an axisymmetric one.
Key words: tangential swirler spillway, the Navier-Stokes equations, differential equation of Rossby, spillways.

Бельгибаев Б.А., Даирбаев А.М-М.
Қиғаш толқынның пайда болуына құйындатқыш құрылымыны әсері

Жұмыс барысында Медеудегі селгеқарсы бөгетінің тангенсалдық құйындатқыш су ағынының жұмыс тәртібі қаралады.Қиғаш толқынның әсері шахтаның бастапқы су лақтыру алаңында тангенсалдық құйындатқыштағы су ағымының ретсіз ағуынан пайда болатыны тәжірибе жүзінде дәлелденеді. Құйындатқыш құрлымын дамыту арқылы бұл әсерді жоғалтуға болады. Тангенсалдық құйындатқыштың төменгі сатысындағы иілу бұрышына байланысты Қиғаш толқынның әсерінің пайда болуына құйындатқыштың құрылымдылық элементтеріне әсер етуі үш өлшемді компьютерлмк модельдеу және анимация әдістерімен есептеу және анализ жүргізілген. Остьтіксимметриялық кеңістік ағым құрылымынан су ағысың тез өтуін қамтамасыз ететін, мысалы Медеу бөгеті, қарапайым және тиімді құрылымдық есептеу ұсынылған.
Түйін сөздер: тангенсалдық құйындатқыштағы су ағымы, Навье-Стокс теңдеуі, Россби дифференциялдық теңдеуі, гидротехникалық құрылысытар.

Бельгибаев Б.А., Даирбаев А.М-М.
Влияние конструкции завихрителя на возникновение косых волн

В работе рассматривается режимы работы тангенциального завихрителя водосброса противоселевой плотины Медео.Экспериментально доказано, что эффект "косых волн"на начальном участке шахты водосброса возникает из-за "перехлестывания"струек тока воды в тангенциальном завихрителе. Этот эффект можно устранить за счет совершенствования конструкции завихрителя. Методами трехмерного компьютерного моделирования и анимации проведен расчет и анализ влияния конструктивных элементов завихрителя на возникновение эффекта "косых волн"в зависимости от угла наклона нижней полки тангенциального завихрителя. Предложено простое и эффективное конструктивное решение, на примере плотины Медео, обеспечивающее быстрый переход потока воды из пространственной структуры течения в осесимметричное.
Ключевые слова: тангенциальный завихритель водосброса, уравнения Навье-Стокса, дифференциальное уравнение Россби,гидротехнические сооружения.

1. Introduction

The Medeo antimudflow dam is the complex hydrotechnical construction, which protects the city from the natural hazard – a mudflow. For water drainage of Small Almaty river and a water component of the mudflow there are dam spillways in the construction. The analysis of the literature and patent researches show that at the modern development stage of hydraulic engineering, the analogues of the Medeo antimudflow dam's spillways do not exist.

At one time, Kazakh scientists-hydraulics developed reference schemes of the constructions and calculation.

It is known that the flow in the mine spillway is described by the Navier-Stokes equations with the appropriate boundary conditions. These equations are nonlinear, the complexity of the boundary conditions for the pressure on reinforced concrete walls of the mine, associated with the occurrence of the effect of "cavitation" can lead to mathematical problems of computational modeling of flow parameters on the inner surface of the mine.

These circumstances require the creation of semi-empirical models based on the search for self- flow in spillway, taking into account the shaft spillway roughness surface, turbulence, hydraulically effects, which are related with unique construction of the spillway swirlers of the Medeo dam.

Algorithms of basic parameters of the Medeo dam spillways, which can be significantly improved at the modern development stage of computer technologies, innovative software products for hydraulic engineering calculation of similar hydraulic structures.

Improving the design of spillways mostly concern the form and method of water supply to the shaft, construction of conjugation and diverted tunnel. This is due to the fact that falling from big height (up to 100 meters) water flow, in the lower part of vertical shaft develops a high speed, which allows the water mass adversely affect the structural elements of conjugation and diverted tunnel. Twisted by swirler the water flow through the longer path of movement and braking on the wall of shaft cannot accelerate more than a certain limit speed.

Necessary to note that the scheme and construction of the Medeo dam spillways, presented in Fig. 1, is designed and presented in practice with considering the most leading technical solutions [1]. The perfection of this design, it reliability and durability indicate a high level engineering practice of Soviet and Kazakh scientists [2].

2. Computer animation of the "oblique waves" effect occurrence in the tangential swirler spillway

On the basis of the general theory of funnel and calculating schemes offered by T. Akhmetov and by simplifying the Nevier-Stokes equations, written in the radial direction of the cylindrical coordinate system with the condition, that the pressure on the free surface equals the atmospheric one, also radian and axial components of the velocity lot less than the circumference, we can get following equation [3]:

$$u\frac{\partial u}{\partial r} - \frac{\vartheta^2}{r} = -g\frac{\partial h}{\partial r} + v\left(\frac{\partial^2 u}{\partial^2 r} + \frac{1}{r}\frac{\partial u}{\partial r} - \frac{u}{r^2}\right). \tag{1}$$

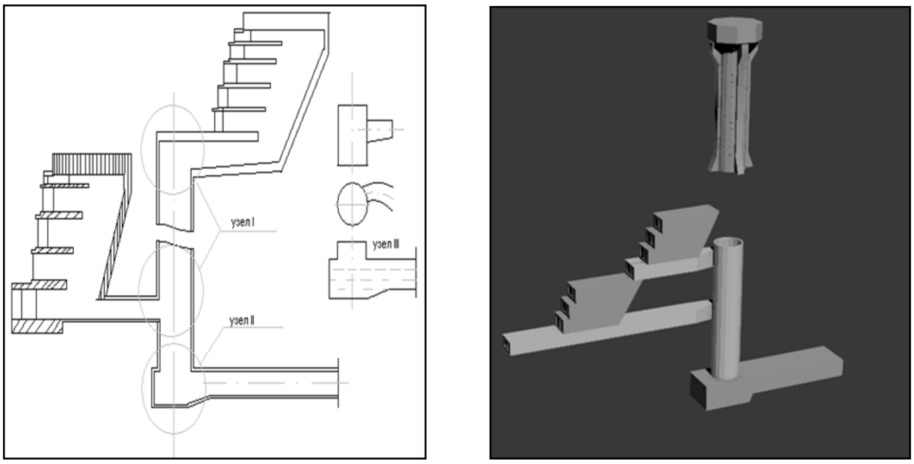

Figure 1 – Cross section of lead galleries, swirl ring, mine host interface and outlet tunnel spillway Medeo

Hence, from area of the flat rotation we get:

$$\frac{v^2}{gr} = \frac{\partial h}{\partial r}. \tag{2}$$

Substitute into equation (2) the rotation generalized law. Calculated schemes for determining the spatial coordinates of the free surface, an axial, radial, and circumferential velocity component in the flow area of the flat:

$$h = H - \frac{C^2}{2gkR^{2K}}, \tag{3}$$

where $C = vr^K$ – parameter of the rotation intensity.

$$u = \frac{Q}{2pRH}, \tag{4}$$

$$w = \frac{C^2 Q}{2pghr^{2(K+1)}}. \tag{5}$$

In the immediate vicinity of vortex, the axial velocity component is proportional to the free fall velocity of fluid particles, which falling from weight (h_0). The axial component of the slip velocity of fluid particles on the free surface of the swirling flow is equal to:

$$w = w_0 + m\sqrt{2(h_0 - h)}, \tag{6}$$

where m – coefficient of proportionality, the values of which can be calculated from the condition that the averaged axial component of the velocity at the entrance to the mine. Estimated values are calculated by the (6) formula.

The numerical solution of modified Rossby's differential equation, taking into account the occurrence of air "cord"in the central part of the swirling flow spillway dam Medeo, surface roughness, turbulent viscosity flow, etc., was carried out by the authors of this project [4]. The resulting table estimated data was used in design process, natural model experiments of the Medeo spillway dam's thumbnails in laboratory, located on the Kazakh Scientific Research Institute of Energy (KSRIE). However, design and debugging of window interface with animated visualization of hydro- dynamic spillways requires software improvement for calculating the parameters of spillway Medey dam. Therefore, in this article there has been tasked to develop an improved program of graphical representation of calculated data of water flow in the spillway of the Medeo dam in 3Ds max environment. Graphical users procedure Draw (R, H) is a part of program characteristics of spillways block calculations. Block-scheme is shown in the Fig. 2. As T. Akhmetov showed the main cause of unsatisfactory performance

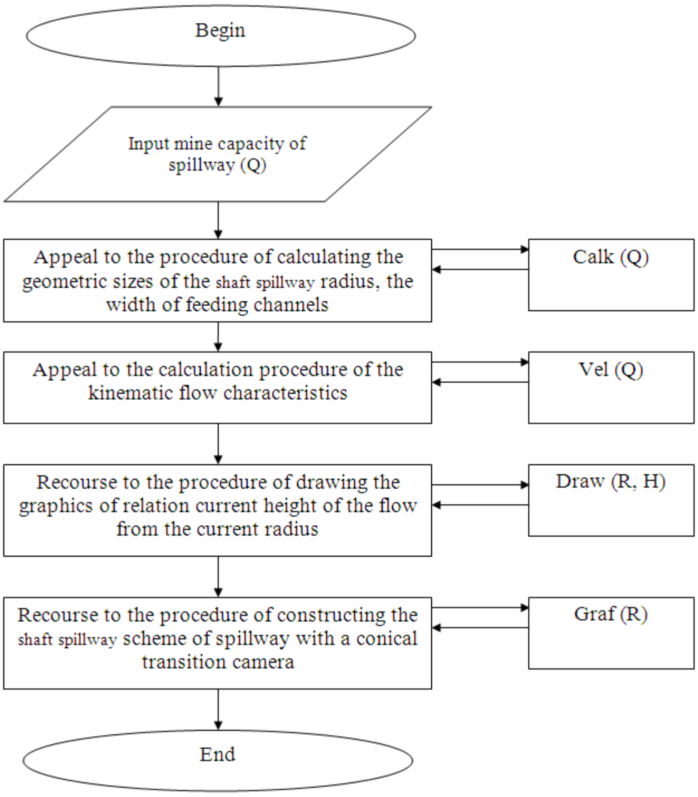

Figure 2 – Block diagram of calculating the parameters of the Medeo dam's spillway

of tangential swirler, which was designed by scheme of S. Slissky, is "the overlapping" surface and bottom lines of the output from swirler (Fig.3).

In the design of the tangential swirler proposed in Moscow Institute of Steel and Alloys in the name of V.V. Kuibyshev by professor S. Slissky, a scheme of supply channel is steeply titled to the horizon, which creates the possibility of adverse hydraulic flow regimes. Qualitative explanation of phenomena, such as collapse of a cavitation bubble, is given in the work of T. Akhmetov, A. Kvasov and D. Djartayeva [5]. In particular, if supply channel has a circular or semicircular cross section, the fluid distribution is uneven, because exterior and interior jet streams are doing a different path and colliding excite oblique waves, which lead to non-stationary flow. To avoid this phenomenon they proposed a semi-empirical dependence for the width of the stream at the point of entry, which should be 0.20 – 0.25 of the shaft diameter. Perspective constructions of tangential swirlers were the subject of special experimental researches (period 1975 - 1982 years), by KSRIE Energy Laboratory models of

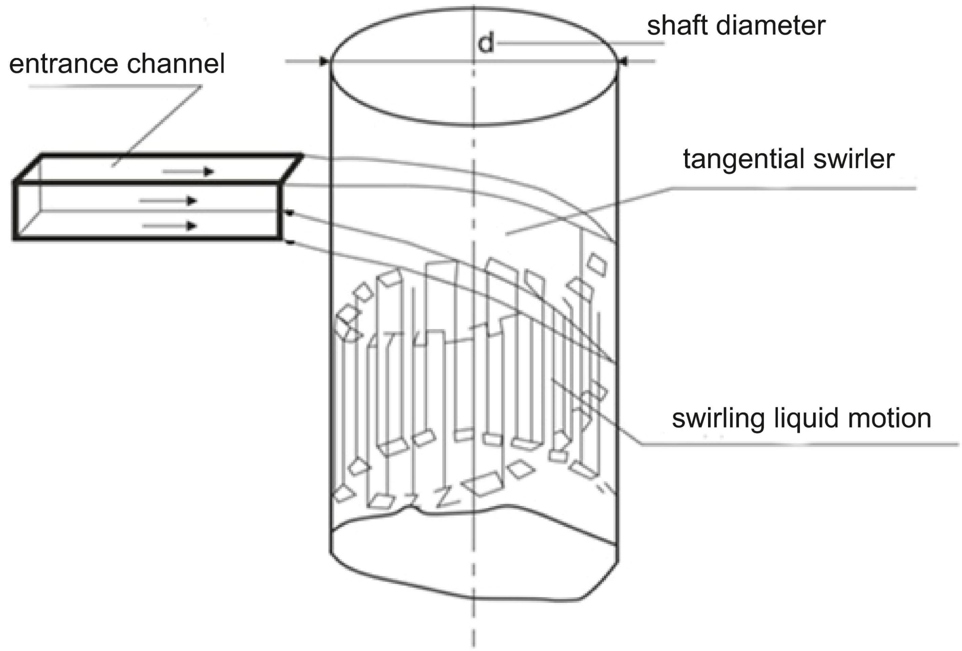

Figure 3 – Kinematics of the flow in a tangential swirl of T. Akhmetov's design

different sizes, which made of plexiglas. As a result of these works there were invented tangential spillway with two water supply and tangential spillway with a conical transition chamber and swirler [6]. As part of the research for this project by means of three-dimensional animation based on the equation of Rossby there were modeled the kinematics of the occurrence of the "oblique waves" effect. The animated simulation showed the process of mixing two liquid particles moving spirally from different points of tangential swirl spillway of the Medeo dam. These calculations are important in the video monitoring of the Medeo dam's spillways to assess the favorability of the hydraulic regime of the swirler. Single-frame animation picture of development trends in the tangential swirler of the Medeo dam is shown in Fig. 4.

As can be seen in the screenshots it is clearly shown the picture as the top line of the current is gradually catching up on the bottom line of the helical path of the current, which on the third caliber mine are completely mixed with each other [7].

This shows that in the area, which adjacent to the swirler, dimensional water flow structure takes place, as shown in picture 4. On the third or fourth shaft calibers, the particles of water flow completely exchange impulses and acquire axisymmetric flow pattern.

3. Conclusion

Thus, the authors were able by computer animation techniques to analyze the impact of structural elements of swirl on the occurrence of the "oblique waves" effect, depending on the slope of the bottom shelf of the tangential swirl by T. Akhmedov. This creates the prerequisites for creating automatic system of optimization modes of spillway through computer control of the attitude position of the tangential swirl's bottom shelf. It is simple and effective design solution, which allows to provide a rapid transition of the flow from unsteady to stationary axisymmetric flow regime, and it gives additional damping of kinetic flow energy in the spillway under the influence of centrifugal forces.

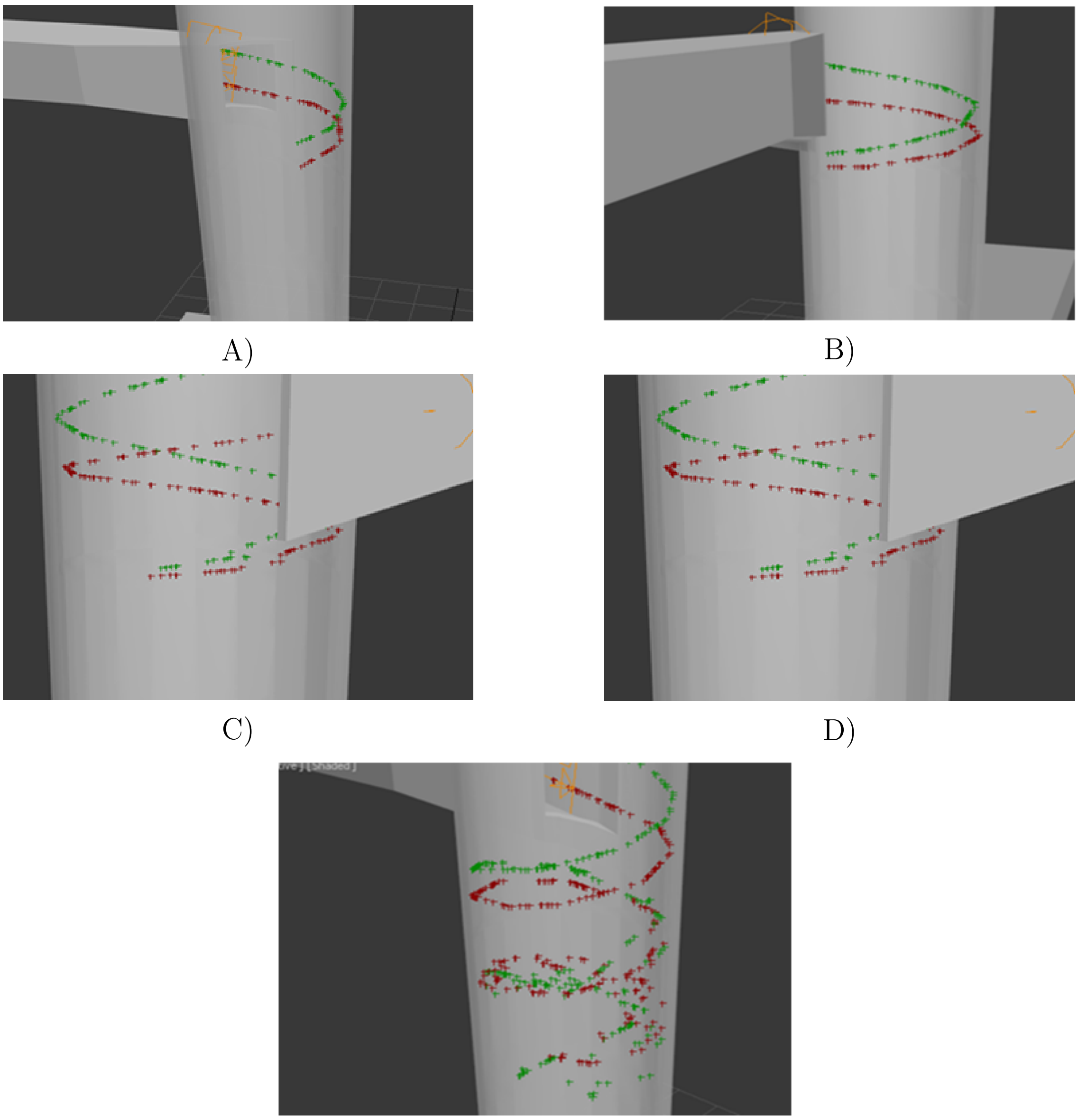

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Figure 4 – Spatial animation using 3D max tools of the "oblique waves" effect

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