Automating the process of resetting the carrier phase of the mudflow to the downstream reach of Medeo dam

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Abstract

The carried-out analysis of catastrophic mudflow in Medeo tract in 1973 showed that the abnormal operation of the dam spillways was associated with several deficiencies in the mud dam's construction and unexplored process of deposition of the solid phase of the carrier medium mudflow mass trapped in the mudflow storage reservoir. Subsequent completion and modernization of spillways was made taking into account the effects of the mudflow in 1973 and now they do not structurally allow catastrophic mud flow cram the mudflow storage reservoir. The article presents a method of controlled dumping the treated fraction from the solid one of of carrying water phase of the forecast catastrophic mudflow through modernized spillways of Medeo mud dam. The proposed approach allows protection from flooding the social-culture objects of Medeo tract through optimal work of spillway that controlled using computer model of automated dam's control and safety system.

Keywords: swirl shaft spillway, hard mudflow phase, hydro technical constructions (HTC), automated control and safety systems

1 Introduction

Nowadays Medeo dam spillways have construction, which consider the deficiency that exposed in 1973 after a catastrophic mudflow. However, in practice, the spillways of the second stage dispose only possibility of overflow from the dam's crest. The factor of existing firm phase during dumping surface water of carrying phase of mudflow mass is left out of consideration. During mudflow mass' "choking" the underlying portals of spillway's headrace tunnels, the overhead spillway portals from short period of time can get out to maximum consumption over 30m3/s. This can cause uncontrolled dumping to the downstream reach of carrying mudflow phase with large solids in the form of rocks, trees residues, etc.

This hypothetical scenario during passage of catastrophic mudflow in Medeo tract can have a number of unacceptable consequences:

- Riverbed of Small Almaty River in the lower reach has a capacity not above than 5m3/s, but high capacity leads to flooding well developed social and cultural infrastructure of Medeo tract situated along the riverbed;
- Big stones and especially granite fragments can lead to strong abrasive destruction of concrete wall of swirl spillway and lead to "choking" a toe basin, which can lead to the full breakdown of spillway dam;
- Mudflow "Choking" of the construction spillway elements, even with successful scenario of surface water release from mudflow storage reservoir, is a negative factor, which related with costly reconstruction works as it did after mudflow in 1973.

The mudslide process in Medeo tract cannot be full-scale modeled. Therefore, the most relevant is a computer modeling with using mathematical tool of computational fluid dynamics of multiphase environment, also using 3D graphical simulation modeling methods [1].

Theoretical analysis of complex hydraulic processes in entrance channel, swirl circular spillway, cushion pool and discharge tunnel requires the plotting theoretical models of moving heterogeneous mixtures of multiphase medium mechanical science [2].

The swirl water flow of dispose masses in spillway is an enhance separation phase process. For swirl shaft spillway the solid phase, in the form of sand and small stones, deviate to concrete surface of spillway by influence of centrifugal forces. It can lead to quick abrasion of concrete embedding and changing geometrical parameters.

As known, Medeo dam spillways have maximum capacity about 30 m3/s, which can fix up with surface water release of mudflow storage reservoir during several days. The main characteristic of these spillways is absence of seals and other control elements of consumption overflow characteristics. The Small Almaty River riverbed was formed by yearly average hydraulically regime of this river. It allows to leave out flow quantity over 5 m3/s without serious negative social-economic consequences in Medeo. The surface water release of mudflow water reservoir, with flow quantity over 30 m3/s during several days, can lead to flooding a number of important sporting and cultural constructions in the lower reach of Small Almaty River.

The purpose of this research is improve the level of controllability of hydro technical constructions (HTC) and spillway work optimization, for safety water release of surface water of mudflow storage reservoir on downstream reach water dam.

2 Overview of the study area

Flat metal hydraulic valves mounted on the front of the receiver portal spillway, eliminate many disadvantages. Their design is shown in Figure 1, and as you can see, they do not require large material costs [3].

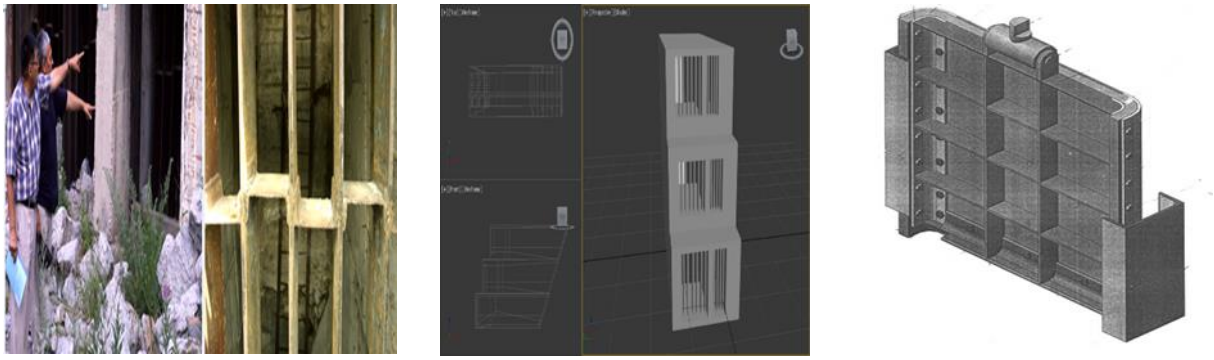

FIGURE 1 Receiving portal, its 3D model and spillway design flat metal gate

Such spillway improvement allows solving some kind of hydraulic problems of Medeo dam spillways:

- Mudflow mass "chocking" of the input portals;
- Decreasing bad influence of "bombing" by massive stones of concrete spillway wall;
- Decreasing influence of sand and small stones to the carrying flow and to the geometrical parameters of Medeo spillway dam (Figure 2).

The better scenario of this situation, after mudflow passing in Medeo and its holding in mudflow storage reservoir, is defecating the mudflow masses during two – three days. In this case, the mudflow storage reservoir can be like large sinker, which should prepare high layer of carrying mass to emergency closing stage - process of surface water release through spillways dam in downstream reach.

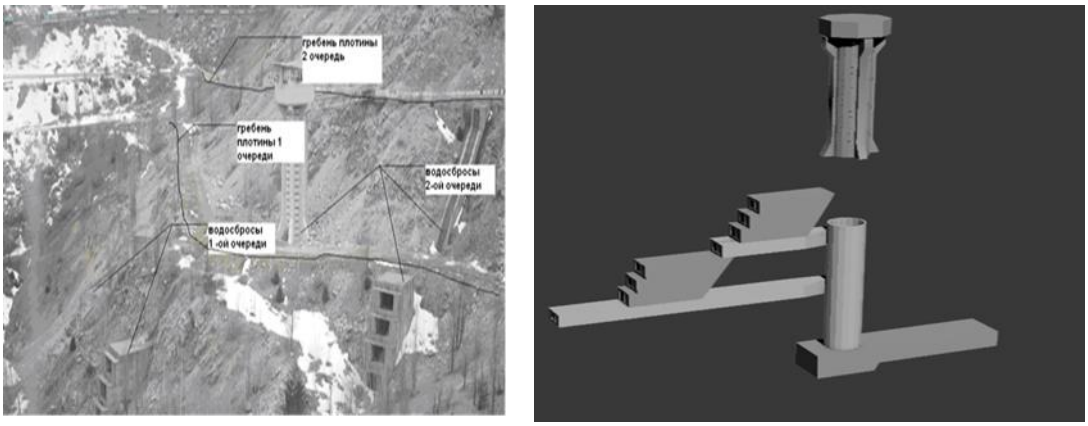

FIGURE 2 Antimudflow Medeo dam and 3D model of spillway construction elements

The process of firm phase separation from carrying environment represents a complex process of impulse and energy exchange in some continuum of entire medium that includes liquid and solid phase.

For quantitative time estimation of coarse particles of firm phase, there is proposed the following methodic of the calculation safety time of settling the carrying masses of mudflow storage reservoir and most probable solid particulate size, which will be thrown off Medeo dam spillway.

There is estimated safety technology of clarified surface water release of mudflow storage reservoir during catastrophic mudflow contains from following steps:

1) Mudflow moves at high speed along Small Almaty riverbed and near input of mudflow storage reservoir; so, because of sudden expansion of "live" canal the flow speed significantly reduced.

2) This effect ensures project impact force on the body of the dam, with a capacity up to 12 million cubic meters, which is equivalent to more than two volume mudflow mass of 1973 year.

3) Input portals of mudflow dam is realize circulation motion in closed space of mudflow storage reservoir. It should be good for firm phase equitability in overall total of mudflow mass.

4) Finishing the circulation flow motion in mudflow storage reservoir is an initial time point of gravitational process of firm phase disposition.

5) The settling time is calculated by the algorithm that created via a computer interface, which ensures deficiency solid particles, from 1mm diameter and above, in surface discharge water.

3 Adopting relevant technology

The gravitational settling is considered in hydromechanics like complex process of separation the heterogeneous stationary systems, in which main factors are the gravitational forces, force of Archimedes and force of sticky, interfacial interaction (force of fraction between particles and carrying phase, during high concentration of solid particles).

During low concentration of firm phase, the computation is carried out in the case of absence of mutual influence particles to each other, and it represents the Stock's task in classical view.

Stock formula shows laminar condition of spherical form of solid particle affected by gravity force, Archimedes force and resistance force of medium:

$$\mathrm{Re} < 2;\ \xi = \frac{24}{\mathrm{Re}};\quad \mathrm{W_{oc}} = \frac{\mathrm{d_ч^2}\left(\rho_ч - \rho_{cp}\right)g}{18\mu_{cp}}, \qquad (1)$$

where ξ – coefficient of medium resistance;

$\mathrm{Re} = \frac{\mathrm{W_{oc}}\rho_{cp}\mathrm{d_ч}}{\mu_{cp}}$.

While flow turbulence, under the action of inertia forces, occurs the boundary layer separation for moving the solid spherical particles, which leads to a turbulence flow to solid body. The deposition rate in the transition mode calculated by the semi empirical formula of Allen:

$$2 < \mathrm{Re} < 500;\ \xi = \frac{18.5}{Re^{0.6}};\ \mathrm{W_{oc}} = 0{,}78\frac{\mathrm{d}^{\,0.43}\left(\rho_ч - \rho_{cp}\right)^{0{,}715}}{\rho_{cp}^{0{,}285}\mu_{cp}^{0{,}43}}. \qquad (2)$$

In the automodeling mode of gravity force, significantly override from viscose friction. Calculation is doing by I. Newton formula:

$$\mathrm{Re} > 500;\quad \xi = 0.44;\quad W_{oc} = 5.46\sqrt{\frac{d_ч(\rho_ч - \rho_{cp})g}{\rho_{cp}}}. \qquad (3)$$

Lyaschenko's approach is more general algorithm, which is used for generality mode of particle flow and its form. This approach was the basis of computer interface algorithm. It is also a part of the planned in program Flow Vision, MasterScada module of automated control system, of technological process (ACS TP) "Clarification of surface water of mudflow storage reservoir" [4-8].

A generalized block diagram is shown in Figure 3.

There is more complicated calculation algorithm of settling firm phase speed in case of mutual particle collision, because of high concentration.

In continuum model, these forces take in consideration in the viscosity coefficient by Boussinesq. However, for practical measurements these approach less appropriate. The important finding of these calculations is increasing energy flow losses that related with impulse interchangement between particles and carrying phase.

The increasing of resistance coefficient at high concentration of firm phase leads to decrease by twice the settling speed. For higher-precision necessary to get semi-empirical form:

$$\mathrm{W}=\mathrm{f}\,(\mathrm{Wc.oc},\ \mathrm{Соб}), \qquad (4)$$

where W – speed of hindered settling, m/s; C – volume concentration of liquid mudflow phase.

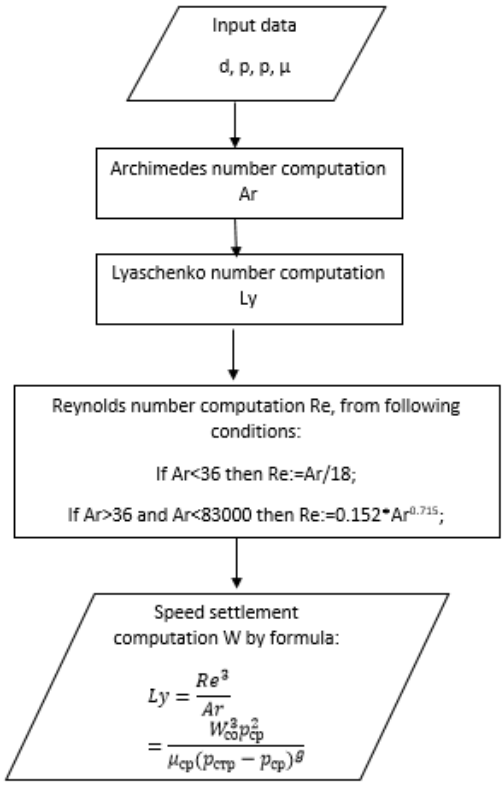

FIGURE 3 Block scheme of speed settling calculation of solid particles in case of concentration firm phase before 10%

Graphical method of calculating the deposition rate of particles is implemented in a heterogeneous mixture which released in Lyaschenko's nomogram that is shown in Figure 4.

In the case of deposition particles rate calculation with irregularly share, there is introduced φ coefficient, which is directly proportional the particle area and inversely proportional the spherical particles area with similar volume.

Described algorithms underlie the basis of the projected automated control system and safety dispose process of clarified water of Medeo dam's mudflow.

For carrying out a manual mode of the control process of surface water release of mudflow storage reservoir there is used the hybrid control technological process scheme. It is based on remote video monitoring of mudflow storage reservoir and inclined drop in downstream water. Using the SCADA-system there was engineered the hierarchy of control objects for developed automated control system of technological process named "Spillway" (Figure 5).

These lists of OPC-Server configuration allow interaction with video monitoring, estimation sensors of the clarified settling of carrying phase in mudflow storage reservoir, and kinematical flow parameters in spillway construction elements that depending on regulated servomechanisms position of ACS TP.

The proposed configuration of ACS TP shows characteristics of high-speed process of clarified surface water release of mudflow storage reservoir through Medeo dam spillways constructions.

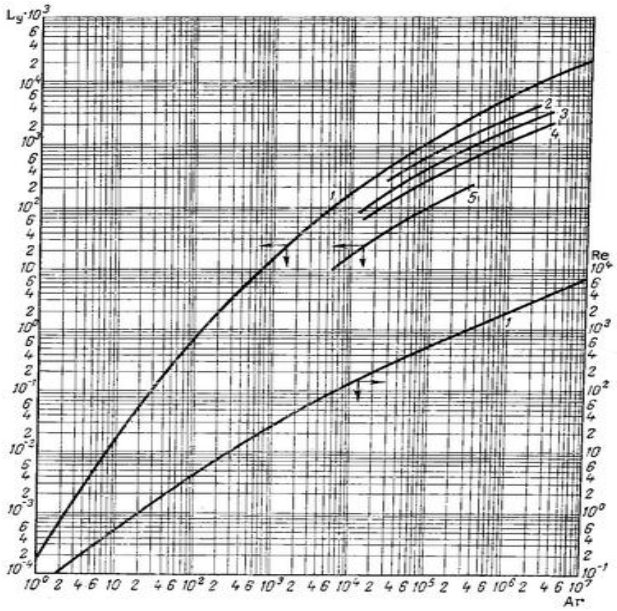

FIGURE 4 Semi-empirical depences of Ly and R parameters by Ar for settling particles in stationary medium:
1 and 6 – spherical particles; 2 – round; 3 – angular; 4 – extended; 5 – sheetlike

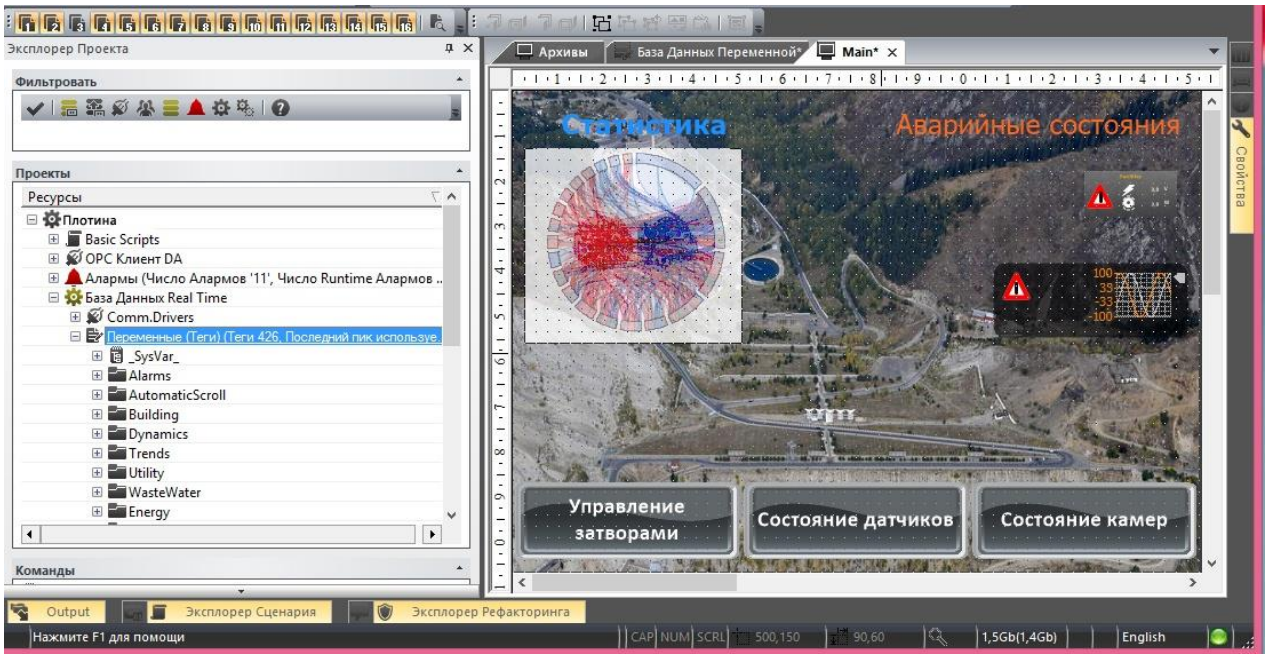

FIGURE 5 Configuration settings of OPS-Server of ACS TP “Spillways”

4 Conclusion

So, the heterogeneous mudflow mass moving in Medeo dam spillway is a complex movement of multiphase environment, which consists from water, stones, clay, rocky soil, etc. Addition of the effective viscosity by Boussinesq coefficient allows reducing problem of moving mudflow to simplified Navier-Stokes equations. In this case the concentration of solid phase where viscosity of carried phase is considered on 10-30 percentage upper water viscosity.

It allows take into account the influence of solid phase to changing of water flow in spillway shaft. Severe abrasion wear of shaft concrete surface related with presence in carried environment the split granite, stones, gravel and sand can lead to divergence geometrical parameters of HTC and initiation some of risks for spillway.

Operating experience spillways in mode of surface water release of catastrophic mudslide in 1973 showed that there was a "blockage" spillway shafts and "draining" of mudflow storage reservoir carried out through the top of the dam only after 3-4 days, after delivery of powerful pumps and spillway setting up. During this time, the firm phase had time to settle to the bottom of mudflow storage reservoir, and a pump is pump out the water with low concentration of sand.

The proposed method of surface water release via Medeo dam spillway allows continuous increasing the

escape water quantity mass up 3-5m3/s. This will provide secure mode of surface water release of mudflow that stopped in mudflow storage reservoir for 3-4 days after mudflow avalanching.

Conducted research changes the conceptual approach to Medeo dam spillway exploitation. This requires regulated metal settle seals and updating existing directory materials by exploitation intake portals of Medeo dam spillways.

The use of automated control system with regulated seals and appropriate sensor during surface water seals of carried environment of Medeo mudflow storage reservoir, allows increasing security of Medeo dam and keeping unique nature boundary.

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References

[1] Belgibayev B, Bukesova A 2013 Computer monitoring and modelling hydrotechnical constructions Medeo dam *Fundamental research* №11 part 9 1784-8
[2] Marishkino A, Zharov A, Zhigalin S 2013 Water seal of spillway flat surface *Russian Patent* №2483156
[3] Belgibayev B, Dairbayev A, Ramazanov E, Korzhaspayev A 2013 Mathematical modelling, numerical methods and complexes of programs *Actual problems of modern science Moscow* №4 265-67
[4] Pyavchenko T, Finayev V 2007 Automated information-control systems *Taganrog State University*
[5] Belgibayev B, Dairbayev A, Dairbayeva S 2014 Methods of determining the surface roughness on the 3D models *The 12th International Conference Information Technologies and Management Information Systems Management Institute Riga Latvia April 16-17*
[6] Belgibayev B, Dairbayev A, Dairbayeva S 2014 Determination of surface roughness using three-dimensional graphics computer modelling and simulation *International scientific and technical conference 2-4 July st. Petersburg State Polytechnical University* 92-4
[7] Kondranin T, Tkachenko B, Bereznikova M, Evdokimov A, Zuev A 2005 Application of applied program packages in the study courses of fluid mechanics and gas *Textbook - Moscow Institute of Physics and Technology Moscow* 104
[8] Belgibayev B, Bukesova A, Korzhaspaev A 2013 Computer modelling of medeo dam spillways in the flow vision technology *Joint issue of journal "Вестник" of D. Serikbayev East Kazakhstan State Technical University and Institute of Computational Technologies Siberian branch of the Russian Academy of Sciences Computational Technologies* part 1 79-82

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