International Journal of Engineering, Science and Mathematics
Vol. 6 Issue 8, December 2017,
ISSN: 2320-0294 Impact Factor: 6.238
Journal Homepage: http://www.ijesm.co.in, **Email: ijesmj@gmail.com**
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

LIMITATIONS FOR OPTIMIZED PARAMETERS OF THE SITES OFINTERACTION OF RESERVOIRS WITH PRESSURE NETWORKS FOR WATER SUPPLY SYSTEMS

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Abstract

Results of the studies of parameter optimization problems for water supply systems are given in the paper. The research results allowthe specialists to define the limitationsfor optimized parameters of water supply systems for practical calculations. The limitations for optimized parameters have been defined for the interaction site ofreservoir and pressure network.The paper proposes a formula to calculate the limitations on resistance coefficient for supply water passage to reservoir. Under these limitations the planned use of reservoir capacity and the stability of computational process are ensured.

Introduction.

In the Republic of Uzbekistan a great attention is paid to the improvement of water resources management and water supply and water use systems. Sustainable socio-economic development is not possible without a sustainable water supply system.

Growing volumes of water consumption and deterioration of water quality under the influence of natural and anthropogenic factors are worldwide problems, burdened by water scarcity. The Republic of Uzbekistan is no exception. At the same time with the growth of settlements the new sites are connected to existing water supply networks. In practice, this sometimes leads to a significant deterioration ofwater supply systems,previously well-functionedones [1].

As the results of analysis show one of the main causes of such poor state is an insufficient development of the methods of calculation of water passages, which are used in such conditions;they do not allow to determine the optimal network parameters to meet the requirements or their optimal reconstruction under new mode of operation.

Currently, the operation of utilities is mostlyaffected by inner wear of existing networks and facilities, communications and equipment, limitations related to the conditions of the availability of water resources and indeterminacy of water use regime. The authors of the paper have developed a search system: for optimal parameters of water supply networks at project stage and search of options for optimal reconstruction of existing water supply networks [2,3]. But there appeared an opportunity to improve the computing power of the system. This paper is devoted to realization ofthis opportunity.

Object, problem and research method.

The object of the study is a"reservoir-supply pipeline"block. The problem to be solved is to determine the limitations for optimization problem; under these limitations the reservoir capacity is used almost in its gross capacity. The method of research is a mathematical modeling of hydraulic phenomena.

In numerical calculations of differential equationsthe researchers meet the limitations on design steps in mutual relation of steps in space and time. Under violation of these limitationsthe solutions begin to oscillate with increasing amplitude and the calculation process (conducted manually or by means of computers)is brought to a stop.

This problem enters the optimization calculation system of water passages, developed earlier by the authors of this paper [2]. Without the introduction of the limitations on hydraulic resistance of water passages connecting the reservoir with the rest of the system the calculation is impossible. The system when searching for the optimal network settings and searching for optimal parameters on the whole range of hydraulic resistance (from zero to infinity) falls into the area of numerical oscillation and could not get out of this area byany solution.

Arbitrarily given and guaranteed sufficient resistance of the pipeline near the reservoir reduces the certainty that the system has defined the optimum characteristics of water passage system for reservoirs. In order to reasonably determine the lower resistance of water passage system connecting the reservoirs with the rest of the system the problem is solved of emptying/filling the reservoir and the obtained solution is analyzed in conjunction with an acceptable calculation step intime.

Solution of the problem of interaction between the reservoir and the pressure network

Initialequationistakenfrommathematicalmodelbuiltandsolvedbythe authors for the search for optimum parameters in water supply systems [1,2].

Water balance equation forreservoirs

Water balance equation forreservoir (in case of one supply pipe):

$$\frac{\partial W}{\partial t} = Q_{in} + Q_{out} - Q_{loss} \quad (1)$$

$$H_r = f(W) \quad (2)$$

Equation of water flow through the system of supply pipes:

$$Q_{in} + Q_{out} = \psi(H_s - H_r) \quad (3)$$

Boundary conditions

$$H_s = \theta(t) \quad (4)$$

$$H\big|_{t=0} = H_0 \quad (5)$$

Where:

W - is a water volume in reservoir (m^3),

t - atime (sec),

$\frac{\partial W}{\partial t}$ - atimederivativeof water volume in reservoir (m^3/sec),

Q_{in}, Q_{out} -an inflow rate into reservoir, outflow rate from reservoir (m^3/sec),

H_r - awaterlevelin reservoir (m),
H_s -aninlet water pressure in supply pipe to reservoir (m),
$Q_{in} + Q_{out} = \psi(H_s - H_r)$ - a function relating the pressure difference in the system and the water level in reservoir with water discharge rate insupply pipe (m^3/sec⇔ψ(m)),
$H_r = f(W)$ - adependence function of water level in reservoir and volume of water in reservoir(m⇔f (m^3),
$H_s = \theta(t)$ - agiven chronological course of water pressure in the system (m),
$H|_{t=0} = H_0$ - agiven initial position of water level in reservoir (m).

In constructing the model an assumption is accepted - the absence of inertial forces at water flow in a supply pipe to reservoir.

Despite the fact that the function ψ connecting the crosshead to water flow in supply pipeline is a difficult empirical function (different authors use different versions of this function), its main feature is that at zero crosshead zero water flow is ensuredand the function is an increasing one relative to the variable –the crosshead -$(H_s - H_r)$. This means that it can be linearized. This means that at small change in pressures in the system the complex function ψ in (3) can be approximated by a linear functional –

$$Q_{in} + Q_{out} = A \cdot (H_s - H_r) \tag{6}$$

This approximation is introduced only to assess the properties of possible solutions obtained, since the analytical solution of the model when usingthe detailed and complex function ψ is impossible.

So, assume that the reservoir is formed by a cylindrical surface with a constant (in height)area of horizontal section

$H_r = f(W)$ is transformed into

$$H_r = \frac{W}{Sr} + \mathrm{Hsr} \tag{7}$$

Where:A -isalinearized function ψ (m^2/sec)

Hsr–a constant with dimensions, m;

Sr -anareaofhorizontalsection in the reservoir (m^2).

It is assumed to solve the problem at harmonic change of boundary conditions (initial conditions are set arbitrarily). The equations of the model are written and solved in analytical form, provided that the boundary condition (the chronological course of the pressure in water supply system) is given by a sinusoid. The way to solve this type of equations is known [4]:

$$\frac{\partial \mathrm{Sr} \cdot H_r}{\partial t} = Q_{in} + Q_{out} \tag{8}$$

$$Q_{in} + Q_{out} = A \cdot (H_s - H_r) \tag{9}$$

$$H_s = B \cdot \sin(\omega t) \tag{10}$$

With transformations the system has the form:

$$Sr \frac{\partial H_r}{\partial t} = A \cdot \left[B \cdot \sin(\omega t) - H_r \right] \tag{11}$$

Establishing the stability in regularityof water level change has a damping exponential curve - $e^{-\frac{A}{Sr}t}$.

Then

$$H_r = \frac{A \cdot B}{Sr} \cdot \frac{1}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} \left[\frac{\frac{A}{Sr}\sin(\omega t) - \omega \cdot \cos(\omega t)}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} \right] + e^{-\frac{A}{Sr}t} \cdot C_2 + C_3$$

(12)

Itcouldbeconsideredthat the components $\frac{\frac{A}{Sr}}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} \to \cos(\phi)$ (13)

and $\frac{\omega}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} \to \sin(\phi)$

(14)

the sum of squares of component (15) and (16) is equal to unity.

So, the components are a sine and cosine of a certain angle ϕ and then, as described in [4]:

$$H_r = \frac{A \cdot B}{Sr} \cdot \frac{1}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} [\sin(\omega t - \psi)] + e^{-\frac{A}{Sr}t} \cdot C_2 + C_3 \quad (15)$$

Here the angleis $\phi = Arcctg\left(\frac{\frac{A}{Sr}}{\omega}\right)$

(16)

In steady-state mode the process is displayed by the equation

$$H_r = \frac{A \cdot B}{Sr} \cdot \frac{1}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} [\sin(\omega t - \phi)]$$

(17)

Or more simply,

$$H_r = \frac{A \cdot B}{Sr} \cdot \frac{1}{\sqrt{\left(\frac{A}{Sr}\right)^2 + \omega^2}} [\sin(\omega t - \phi)]$$

(18)

$$H_r = \frac{B}{\sqrt{1 + \left(\frac{Sr}{A}\right)^2 \cdot \omega^2}} [\sin(\omega t - \phi)]$$

(19)

The obtained formula shows that the larger diameter *A* of supply pipe and the smaller the area of horizontal cross-section ofreservoir the less different the course of levels in reservoir from the pressure changes inexternal system. However, with small cross section of supply pipe to reservoir (high resistance), there is no time for reservoir to be fully emptied or filled. The amplitude of the course of levels in the reservoir is always less than the amplitude of the course of pressure in external system, measured in meters of water column. In order to provide the certainty on this issue it is expected to determine the percentage of the work efficiency of the reservoir.

If toassume that the work efficiency of the reservoir is N (for formula (20) N = 99%) it is possible to determine the maximum resistance to friction of supply pipe.

$$\sqrt{1+\left(\frac{Sr}{A}\right)^2\omega^2} = 1{,}0101 = \frac{1}{N} = 100/99 \tag{20}$$

From (20) it is easy to calculate the resistance coefficient (that is, a linearized coefficient of resistance) of the supply pipe when providing N percentage of the use of reservoir volume

$$A > \frac{Sr}{\sqrt{\frac{1}{N^2}-1}}\omega \tag{21}$$

In case of violation of this condition the reservoir cannot be used at set N percent. Frequency ω can be taken as the frequency equal to one cycle per day. Reservoir area can be set on the basis of construction possibilities.

At finite-difference approximation and solution of differential equations (8) and (9) with calculated time step t_n itis necessary to adhere to Courant-Levy rule. The rule states that numerical information cannot be distributed faster than physical information. In our case, this rule is written by formula $\frac{A*t_n}{Sr} < 1$ or $A < \frac{Sr}{t_n}$ (here t_n is a time step at finite-difference solution). So, for supply pipe of reservoirthe upper and lower limitations of resistance coefficientare defined; they guarantee both preset use of reservoir volume and the stability in finding the optimal parameters of the entire water supply system

$$A < \frac{Sr}{t_n} \text{ и } A > \frac{Sr}{\sqrt{\frac{1}{N^2}-1}}\omega \tag{22}$$

Conclusions

1. An exact calculation of the processes of filling and emptying of reservoirs in water supply systems when searching for optimal parameters considerably complicates the calculations. The solutions often become unstable. The practice demands to simplify the mathematical model of optimization of the systems of water supply using the hypothesis of equality of pressure inside water supply system and the water level in the reservoir at each designpoint of time. To do so it is necessary to determine which properties should possess the supply pipelines to the reservoirs.

2. Certain limitations allow to increase the stability of the solution of the basic optimization problem and to speed up the process of its solving.

References

1.Salohiddinov A.T., Savitsky A.G., Ashirova O.A.Mathematical model for calculating the water supply system with the ability to optimize its elements. Irrigation and melioration journal. №1, Tashkent, 2015. 42-47p.
2. Salohiddinov A.T., Savitsky A.G., Ashirova O.A. Theory and calculation of water supply and distribution in the complex of agricultural water supply network. Monograph. Tashkent: 2016, 142 p.
3. Salohiddinov A.T., Savitsky A.G., Ashirova O.A. Improvement of design validation of the elements of water network at strategic development of villages", Barnaul, 2014. 476-479p.
4. Piskunov N.S. Differential and integral calculations. For High School students, Volume Two, Publisher "Nauka", Physical and mathematical literature. Moscow 1972.575p.