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APPLICATION OF MATHEMATICAL SIMULATION FOR PROGNOSTICATING RELIABILITY OF HYDRORECLAMATION SYSTEMS ELEMENTS

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Now, mathematical simulation is used in different spheres and this means that scientists use new, more precise and fruitful investigation methods. A model is an object that sufficiently repeats the properties of the modeled object (prototype) that are essential for the aims of the specific modeling and omits unessential properties in what it may differ from the prototype. Mathematical simulation substitutes the investigated object by its mathematical model and then investigates this model by up-to-date computational aids, This is not innovation. From time immemorial, in mathematics, mechanics and other fundamental sciences mathematical models were used as a device for describing and studying objects and phenomena. Methodology of mathematical simulation develops rapidly and covers all new spheres beginning from elaboration and control of great technological systems to analysis of complicated economical and social processes. In order to understand the essence of a mathematical model it is necessary to consider it on the example of construction of a model for calculation reliability of hydroreclamation systems. The first stage of simulation is consideration of some empiric situation, definition of optimal indices of elements of pumping plants for increasing operational indicators. At this stage, a new comprehension of the problem happens and this reduces to revealing basic or essential properties of the phenomenon. Some features of investigation are important the other ones are unessential. For example, for designing efficient technology, we need technical characteristics, operational indicators. It is not important who is the owner of this production unit or how many people work at this unit. Our goal is to create such a model that could give more precise recommendations on the work of pumping plants, prediction on realization of their economical productivity. The next stage is the problem statement. But before to go over to it, adequacy of the stated problem should be verified. At the second stage, essential quantities revealed previously are converted into the term of mathematical quantities and relation rules between them. The secondary separation of essential and unessential ones, i.e. separation of indices that essentially influence on the phenomenon and slightly change the final result, happens at the second stage. For example, to calculate "loads" in pumping plants, we should know indices of the worst operating condition, the amount of powerful and weak units. But it is not a whole spectrum of components that influence on a final result in this or other degree.

While constructing this mathematical model, at this stage all unessential components (thinly influencing) were thrown giving up their place to deeper study of essential quantities. Simultaneously, in the problem statement process, the equations and the systems of equations for its solution are choosen, exclusive situations, initial conditions and others are considered. The next stage is the mathematical model itself. The ways and methods of its solution, application of these or other transformations for special simplification of the problem are considered. While using data base, these data may be unloaded from the knowledge data. This may save time for more thorough calculation of other indices that provides a great accuracy of the results. And again, verification of correctness is realized. The model itself must be non contradictory and subjected to all postulates of mathematical logics. Furthermore, consistency of the constructed model and initial problem is verified by comparing the obtained theoretical results with the available experimental-operational results. The aim of elucidation is to know if the model widely reflects the problem or it is only its small part bounded by some parameters.

Then the prognosis is realized, plots are structured, numerical results, tendencies and etc are given. The situation is modeled for different aims. The main of them is to predict new results, or reveal new properties of the phenomenon. Application of computers for mathematical simulation changed the notion to solve a problem'. Now, calculation experiment may be con ducted for apart of second. Only, an algorithm for calculating a model should be elaborated and programmed correctly. Simulation is the first step to conduct computational experiment. Unlike life experiments, a calculation experiment takes few time, allows to accumulate the results obtained while investigating some class of problems and then rapidly and flexibly to apply them to the solution of problems of absolutely different fields. The more thoroughly worked out all the parts of computational experiment, the more precise will be the results of the experiment and the investigator may deeply understand the object's nature.

Pumping plants pump over water in many systems of irrigation, water-supply drainage, heating, heart supply and etc. With definite probability they shouldn't allow interruptions of water supply or these interruptions shouldn't exceed a day [1].Failure of pumping plants may cause great financial and material losses, since they are a part of water supply in water supply and water removal systems. Therefore, their failure may reduce to irreversible loss of some elements of the system. This illustrates importance of study of estimation methods of reliability of pumping plants and the methods of increase of their reliability. The basic equipment of pumping plants are divided into technological (mechanical) and electrical parts. The technological part contains: pumps, pipelines in the plant, check valves: the electric part contains: electric motors of pumps, starting and distributive devices, the elements of automatics, transformers. The failures also may be divided into failures of mechanical and electrical parts. It should be noted that failures of the electrical part are failures observed practically 10 times rare than of the mechanical part [1,2]. Therefore, in reliability calculations, it is admissible to take into account only a mechanical part of plants pumping. Duration of mean-time between failures, in great degree is determined by the wear of rotating parts, vibration, disbalance and corrosion. The most typical cause of failures is the wear of bearings. Breakdown of isolation of the rotor or stator damage of labyrinth seals may be the main causes of failures in the electrical part mean-time between failures of the pumps produced in Community of independent countries composes [3]:

- at horizontal pumps 4000-5000 hours: $\lambda = (2{,}5 \div 2)\cdot 10^{-4}, 1/$ hour
- at immersion ones 6000-8000 hors: $\lambda = (1{,}67 \div 1{,}25)\cdot 10^{-4}, 1/$ hour

The pumps produced in foreign countries have operation time usually within 10-12000 hours, the pumps with wet rotor up to 40000-70000 hours without servicing. Failure rate of the pumps of type ND and SD is $1{\cdot}10^{-4}$ 1/hours, of electric motors up to $0.26{\cdot}10^{-4}$ 1/hours. For the pumping units on the whole (a pump, two bolts and electric motor) the failure rate is recommended to accept to $1.6{\cdot}10^{-4}$1/hour [3].

Depending on the level of requirements to steady water-supply, according to SNP 2.04.02_84, the pumping plants are divided into 3 categories that correspond to water - supply systems categories. Normative valves of availability factor for them were calculated by the requirements of SNP 2.04.02_84. In principle, the reliability parameters of pumping plants should correspond to reliability parameters water-supply systems of appropriate category. At the same time, some other quantities of reliability parameters are reduced for hydroreclamation systems.

A pumping plant is an ordinary technical object and its reliability parameters are calculated by the standard method. There, relatively difficult stage is to compose a structural logical scheme. It should include all the elements that essentially influence on its reliability If in the plant the pumps are set for-flooding lower than water level in the reservoir wherefrom water is taken, then the underground part of the engine- room should be separated into two sections by means of blind barrier. This allows to protect from flooding the pumps and specially, electromotors in one part when steel reinforcements and pipeline an in another section are broken. Generally speaking, measurements against flooding of lowered engine room should be considered more thoroughly.

Possible application of vertical pumps with motors taken out above the ground mark at the plant SNP 2.04.02_84 stipulates steady water-supply by installing reserve units.

The amount of operating units of one group for pumping plants of first category should be at least two. Maintenance of capacity for work of pumping units is provided by scheduled-preventive and overhaul repairs. According to references, running repairs are conducted as required, but at least once in three months. In such case, operation time of the pump may compose 2160 hours. Overhaul of pumps are carried out after no more than 8000-10000 hours of operation time. After running or overhaul repairs the pump is equally useful as a new pump by the reliability parameters. For such objects, the notion of availability factor and probability of no failure operation are identical. This enables to consider the value of normative availability factor equal to admissible quantity of probability of no-failure operation $P_{don.}$ Admissible duration of period between repairs P_{don} may be calculated proceeding from $P_{me;pem}$

Let's consider a procedure of reliability estimation of the pumping plant. We assume that the stage of checking technological and hydraulic calculations has already been executed and the pumping plant corresponds to acting norms and rules. For simplification, it is admissible to exclude communications in the station from the structural logical scheme of the pumping plant. We assume that from the reliability point of view, the communications and constructions of the engine room have been worked out properly and they don't have essential effect on the reliability parameter of the station. Operating units in the structural-logical scheme should be connected successively, since failure of any unit leads to lowering of expenses, I, e failure of the plant on the whole failure units are represented at one side and wait for substituting any failure operative unit. There are some variants of calculation of reliability parameters of pumping plants. We suggest a simplified method with using complete probability formula by constructing failures tree and mathematical logics and also theory the queuing system. The two first methods stated below are the simplest ones.

a) Simplified method of reliability estimation of the pumping plant.

At the pumping plant with k workers and *l* reserve 1 units for redundancy multiplicity

$$m=n/k$$

and active redundancy we suggest, the availability factor to calculate by the simplified formula:

$$K_0 = r\mu/\left(r\mu + J/(1+m)\right), \qquad J = \sum_{i=1}^{k} \lambda_i$$

And mean time between failures. T by the formula:

$$T = T_0(m+1)$$

Here *r*- is the number of repair teams, more often one team, *r=1*
μ -is recovery rate of the pump unit,
λ- is failure rate of the pump unit,
T_0- is mean-time between failures, $TO = 1/\lambda$ hour:

b)Reliability calculation with using total probability formula.

Here we use that total probability of being of the system in no-failure state equals the sum of probabilities of all different no-failure states of the unit. For a pumping plant with k operating and k reserve units, for uniform units the number of such states will be (*n+1*):

1) all (*k+n*) units are serviceable:
2) when one unit fails, the number of the serviceable units equals (*k+n-1*)
3) when two units fail, the number of the serviceable units equals (k+n-2)

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(n+1), when n units fail, , the number of the serviceable units equals k.

It more than n units fail, the number of operating units will be less than k and the pumping plant will not supply calculated amount of water, i,e., it will pass to the failure state. Thus, many scenario may be suggested for different specific amount of pumping plants. In the general case:+.

$$K_{(n+k)} = k^{n+k} + C_{n+k}^{n+k-1} k^{n+k-1} (1-k) + C_{n+k}^{n+k-2} k^{n+k-2} (1-k)^2 \ldots\ldots\ldots\ldots k(1-k)^{n+k-1}$$

Calculations show that increase of operating units by preserving constant amount of reserve units reduces to lowering of availability factor K of a pumping plant. In particular, for the availability factor of the unit k=0,9 and the number of reserve units equal 2 increase of the number of operating units from 2 to 5 reduces to lowering of the availability factor of the plant by 0,022, i,e by 2,2%

References

1. Samarski A.A., Mikhailov A.P Mathematical simulation Ideas. Methods. Principles / M.: Fizmatlit, 2001, 429 p.
2. Naumenko I.I. Reliability of structures land-reclamation of systems. Kiev. Visha shkola, 1990, 239 p.
3. Qolinkevich T.A. The applied theory of reliability. Kiev. Visha shkola, 1985, 168 p.
4. Pryajinskaya V-G, Yaroshevski D.M, Levit- Gurevich L.K. Computer simulation in water resources control. M.: Fizmatlit, 2002. 496 p.