MARKOV'S MODEL OF TECHNICAL CONDITION OF THE OBJECT

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In the vast majority of cases, any technical object is under the influence of a large number of randomly variable factors, which, without causing complete destruction of the object, cause gradual changes in the negative direction of its various characteristics. If we are talking about construction objects, examples of complexes of such factors are climatic influences, characteristics of the atmosphere, hydrology of the territory. One of the basic problems solved in such cases is the problem of forecasting the level of degradation of the object during a certain period of time. It is also often necessary to consider the question of the possible term of the object's future operation, that is, the length of time during which its characteristics, with a certain level of reliability, will be preserved within the specified limits. Solving such problems requires:

– complex monitoring of the facility's technical condition during (preferably) the entire period of its operation;

– similar monitoring of influencing factors on its technical condition during the same time;

– availability of information about additional factors that may cause changes in the aforementioned factors;

– availability of information on the long-term impact of possible combinations of external factors on structures and materials used in this facility;

– a mathematical model that allows you to predict with sufficient accuracy the technical condition of the object within the specified time period based on the available.

In the general case, these tasks are the tasks of forecasting the values of a number of functionals of a rather complex structure, built on the trajectories of a multidimensional random process, and the information regarding both the structure of the functionals and the characteristics of the process is statistical in nature with appropriate restrictions on its probability and completeness, which makes the construction of a workable mathematical model is very problematic.

In practice, as a result of actually used procedures for monitoring the technical condition and influencing factors, the investigated process turns out to be a process with discrete time, it should also be taken into account that decisions regarding its maintenance and operational features (up to its termination) are usually also made at fixed moments of time. According to the available regulatory documents, its phase space is also enlarged (discretized). At the same time, the values of some of the building's parameters must be within certain intervals, as they are determined by state regulatory acts, while others are limited due to the specifics of the object's operation. This may concern, for example, such parameters as energy saving, vibration level, protection against noise, dust, electromagnetic disturbances.

Despite the understandable possibility of deviations from the realities of the evolution of the object, such a situation has no alternative and provides opportunities for describing this evolution as a chain of events, that is, a random process with discrete time and a properly organized discrete phase space, the elements of which can be, for example, sets of parameter values the object (more precisely, data on their belonging to certain areas of values, determined for reasons of characterizing its general state) and environmental parameters (again, in the sense of belonging to their similarly defined ranges).

In this situation, even if most of the building parameters are described using the binary scale "acceptable-unacceptable", the phase space may turn out to be unacceptably bulky, which will require its enlargement. The corresponding procedure is non-trivial, since in practice it means the need to determine such configurations (sets) of object parameter values that determine certain approaches to its operation, which in turn requires appropriate technical and economic analysis and the formation of business plans adapted to the situation, internal norms, etc. An indispensable requirement for such newly formed clusters of the phase space of the model is the presence of statistical material regarding the frequencies of transitions between them and the influence of such sets of characteristics on the parameters of the building.

A natural mathematical model in such a case is a Markov chain. The primary variant of such a model is the stationary Markov chain, since it is the easiest to study. Fulfillment of the requirements for information provision formulated above allows, by making an additional assumption about the ergodicity of the chain, to build a transition probability matrix of the chain and classify its states based on the available data on the frequency of transitions of the system from one state to another. The adequacy of the model built in this way can be checked by comparing the accumulated frequencies of the constructed Markov chain in its states (or a set of states selected for practical reasons) with the stationary probabilities (frequencies) found on the basis of the matrix of transition probabilities (frequencies) constructed on the basis of observational data. Accordingly, in the case of obtaining confirmation of sufficiently high accuracy of the coincidence of the calculated values with the observed ones, opportunities

– calculation of the percentage of time the structure is in certain conditions, under certain loads, etc.;

– forecasting the evolution of the levels of degradation of the building's characteristics depending on time;

– forecasting the balance sheet and market value of the building as a function of time;

– calculation of the probable terms of carrying out repair works;

– forecasting operating costs;

– calculation of the probable maximum period of operation of the building according to its technical indicators;

– determination of the probable period of operation of the building from the point of view of maximization of payback and selection of the appropriate mode of its operation.

Observing the technical parameters of the building and the conditions of its operation may reveal significant deviations of its state indicators from those predicted according to the model available at that time, caused by certain factors. It is also possible to "anticipate" correction of the model in accordance with the next change in operating parameters. In case of detection of significant discrepancies between the hypothetical stationary probabilities and sets of empirical frequencies, it is carried out

– revision of the phase space of the model in connection with the change of its characteristics;

– modification of transition frequencies (matrix of transition probabilities of the Markov chain) by removing the most "outdated" source information, after which they are recalculated and the aforementioned comparison is performed again;

– analysis of the available information from the point of view of its “quasi-periodicity” (identification of time periods characterized by the reproduction or close to reproduction of complexes of external factors for the system, for example, calendar years for atmospheric factors) and consideration of differences in the reactions of the system to factors during such “quasi-periods” (for example, "in the worst case");

– detection of time trends (both in system parameters and external factors, and in transition frequencies) with construction of appropriate modifications of forecasts.

It should be noted that the above modifications of the original model are those that should be implemented not only before the start of its use, but also periodically during the entire period of its use in order to maintain the adequacy of the model.

The case of a predicted change in the complex of factors that determine the technical condition of the object during its operation is subject to special consideration. In such a situation, the model is subject to a complete revision, new clusters of the phase space are formed, and the problem of transition probabilities is solved. In the latter case, naturally, it may turn out that there is no statistical material for building a matrix of transitions, which requires a repeated reference to the "history" of this object and, if possible, the search and use of information about its close analogues in the sense of its own parameters, and external influences. A heuristic approach is also possible: "assignment" of the corresponding transition probabilities, taking into account the requirements for the elements of the transition matrix and additional considerations, if any. In each case, such a situation requires increased control over building parameters, which can be provided by reducing the time intervals between measurements, increasing the accuracy of measurements, and duplicating measuring devices.

The Markov model is natural in the mathematical modeling of the technical state of various objects. At the same time, it can be very cumbersome, which requires its enlargement, and is subject to changes that violate the homogeneity in time. Only when these circumstances are taken into account, modeling using the Markov chain turns out to be useful in solving a wide range of engineering, economic and organizational tasks.

References

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